SCIENTIFIC AMERICAN

SUPPLEMENT No. 533

Scientific American Supplement, Vol. XXI., No. 533. } NEW YORK, MARCH 20, 1886. { Scientific American Supplement, $5 a year.
Scientific American, established 1845. { Scientific American and Supplement, $7 a year.

DESIGN FOR A MONUMENT, BY KLOTZ.

ONE of the most talanted and promising of all the sculptors in the Vienna school is E. Klotz. He is distinguished in the study of antiquity, the influence of which is most agreeably shown in his creations.

This monument, of which we present a picture, is one of his best works. A task that has often been put before one is satisfactorily solved by simple means, artistically used. First of all, the appearance of the monument itself is uncommonly pleasing; from whichever side one views it, the effect is always good. The sorrowful woman's figure shows the greatest animation. One notices a concealed sorrow in the beautiful features of her face, which is turned upward toward heaven. The drapery surrounding her limbs is pleasing in its style. The purely ornamental element of the monument, namely, the urn covered over with palm branches that surround it, harmonizes beautifully with the whole.

The work is the fruit of thorough ability, of an earnest endeavor to reach the highest aim of art by the purest means, and this endeavor will certainly meet with success.

DESIGN FOR A MONUMENT, BY KLOTZ.

ARTISTIC BRONZE CASTING.*

By GEORGE SIMONDS.

FEW metallurgical operations have been more wrapped in mystery and shrouded in romance than artistic bronze casting. At the mere mention of this subject the imagination conjures up visions of Michel Angelo, in his grief and disappointment at the loss of a whole year's work by his failure in casting the statue of Julius II., at Bologna; of that equally wonderful genius, Leonardo da Vinci, devoting ten years to the construction of an equestrian statue, doomed to destruction even during his own lifetime; and, lastly, and perhaps chiefly, our thoughts turn to Benvenuto Cellini, who has left us so vivid a description of his own labors, his failures, and his triumphs in this difficult art. And as if the history, as he relates it, were not wonderful enough, modern authors, headed by that prince of romancers, Alexander Dumas, have so extended and exaggerated their original, that to those whose ideas of statue founding are chiefly derived from such sources the process appears almost like a miracle, and the founder a being endowed with superhuman powers.

Most persons in easy circumstances are owners of certain small bronze figures, with which they decorate their mantel-shelves or sideboards, and which satisfy to some extent their natural craving for sculptured form. Few persons, however, have any but the vaguest ideas as to the processes by which these are made. They would probably tell you that they were cast, but that would be the extent of their information.

Two or three years ago, I was modeling a study of a lion in the Lion-house at the Zoological-gardens, and although I, as far as possible, withdrew myself from public observation, yet I was frequently questioned by visitors as to the object of my work, and its final destination. I was often amused and surprised by conversations on this subject between visitors to the gardens. On one occasion a lady and gentleman entered into conversation with me while I was at my work, and after I had explained to them the object of my study, and had told them that the work would finally be cast, they, evidently thinking that they had taken up enough of my time, withdrew a little way, though still looking on, and curious to know more. I overheard something of their conversation, and the lady was evidently anxious to know how the casting was to be done. Her companion explained it to her much as follows: "Oh! well, yes, you see, when they cast a thing in bronze, they melt the bronze, and—and pour it over it!—and then its cast you know." Of course this explanation did not prove quite satisfactory either to her to whom it was given or to him who gave it, and they discussed the subject at considerable length, but without coming to any conclusion that seemed satisfactory to either of them.

It was hardly the time or place for a lecture on statue-founding, so I did not join in their conversation; but I resolved that, should a suitable opportunity present itself, I would not fail to avail myself of it, and endeavor to remove some of the mystery with which this subject seems to be surrounded, being assured that it is to the true interest of art that these matters should be more generally understood. Such an opportunity has been kindly afforded me to-night, and it will be my endeavor to show you, as clearly and as briefly as I may, in what manner the work of artistic bronze casting is conducted.

This subject is so large, that to treat it thoroughly, in all its branches, would require a course of at least five or six lectures, whereas to-night I must endeavor to condense as much as possible, in order to bring it within the limit of time at our disposal. I shall, therefore, omit all historical preface, and refer to ancient examples merely as they may serve in the course of the evening to point a moral. I shall also give much time to the consideration of the waste wax process, as being chiefly suited for the production of autograph bronzes of cabinet size.

Before a work of art can be cast in bronze, it must, of course, be in existence in some other material, and it may not be altogether superfluous to describe briefly the various stages a statue must pass through before it can be introduced to the world as a bronze. The sculptor usually embodies his first idea in a sketch, not, however, in most cases on paper, but in wax or clay.

A sculptor's sketch is simply a statuette, very roughly modeled, and usually not more than five or six inches high. Works of this size do not require any internal framing for their support, and therefore lend themselves readily to any changes of design, even of the most radical description.

The attitude of the figure, the principle, masses of drapery, and, in short, the general arrangement of the composition, having been decided on, the next step is the construction of a full sized framing of iron, without which the statue in plastic clay or wax could not stand, but would yield to its own weight, and sink a shapeless lump to the floor. With the assistance of the iron framing, or skeleton, running through every part, it can be preserved for a sufficient time—often for several years—to permit the artist to bring it to that perfection of which he is capable. But even then it is not to be regarded as a complete work; for this plastic material, whatever it be, is certain to be destroyed by its very plasticity. Therefore, that it may be preserved, it must undergo a transformation which will render it hard and durable. If the statue has been modeled in a certain manner, and with specially prepared clay, the action of fire will produce this result, and then we call it terra-cotta—an excellent material for many purposes, but with which this evening we are not concerned. The only other method of preserving the model is to cast it. By this means, although the plastic model is destroyed, a facsimile is produced in another and more durable material.

Casting involves five processes, to wit—

1. The construction of the hollow mould.
2. The preparation of the fluid material.
3. The casting or pouring into the mould.
4. The solidification in the mould.
5. The liberation of the cast from the mould.

I must now, for a moment, beg your attention to the consideration of moulds. A mould is made over a piece of sculpture by the application of some soft material which has the property of rapidly becoming hard. By this means a concave impression is obtained, from which again, by a similar process, a convex facsimile

* A recent lecture before the Society of Arts, London.

of the orginal model may be produced. There are, however, many kinds of moulds used by artists, and it will be convenient here to give a short account of some of them. The sculptor roughly divides all moulds into simple and piece moulds. A simple mould is made all in one, without any loose parts, like a seal, or a pastry-cook's jelly mould. A piece mould, on the contrary, is made of two or more parts, according to the requirements of the work. Moulds are also called open or closed moulds. An open mould is one of which one side only receives an impression. Simple moulds are, for instance, usually open moulds, so also are piece moulds of bass-reliefs or other flat objects. A close mould is almost always a piece mould, it may or may not be a safe mould. A safe mould is made up of many separate parts, so constructed as to be easily withdrawn from each other. These moulds can be used many times over without injury either to themselves or to the cast—hence their name "safe." A waste mould is made of one or of many pieces, but it can be used only once; it is destroyed or wasted in the process of casting. I wish you to remember particularly these last, the safe and the waste mould, because they are terms that I may have to use very frequently this evening. Moulds are made of very various materials, according to the objects for which they are constructed. Plaster is the most common, but wax and gelatine are also much used by artists. For bronze founding the foregoing materials are unavailable. The sculptor who would cast in bronze must use a material that will resist the intense heat of the liquid metal. Moulds for metal casting are made of sand and loam, of *luto* or *potée*, or, for small works, of compo. Of these we shall have much to say presently.

Let us suppose then that an artist has completed a statue, and, having already cast it in plaster, wishes to reproduce it in bronze. How is he to set about it? If this work is of large dimensions, it is very unlikely that he will have suitable premises for the purpose, for although small works can be cast almost anywhere, no casting on a large scale can be reasonably undertaken unless a suitable foundry is available. Such a foundry should consist of a large and lofty room about 40 feet long by 24 ft. wide, the larger, indeed, the better. A row of small furnaces should be built along the wall at one end, and at the other end should be situated the reverberatory furnace for large work, while a very large portion of the floor should be occupied by the pit. The small furnaces before mentioned are draught furnaces of the ordinary type, and are made to take crucibles up to about 60 lb. capacity. By pouring the contents of several crucibles together, castings of considerable size can be made, even with these small furnaces. Larger quantities than can be conveniently melted in the small furnaces must be treated in the reverberator, which is occasionally made of very great capacity. That which was used for the statue of Louis XIV., cast by Keller in the year 1699, contained no less than 83,752 lb. of metal, which was run down and poured in 40 hours after the furnace was started.

The pit of which I have spoken is used to bury the moulds previously to casting. This is with a two-fold object: partly that the pressure of the earth outside the mould may enable it to resist the pressure of the metal from within; and also in order that the openings through which the metal is poured may be placed at a convenient level, which would not be the case if large moulds rested on the floor of the foundry.

Besides the large and small furnaces, and the pit which I have just mentioned, our artist would also require at least one blacksmith's forge and a powerful crane, not to mention drying stoves and pugging mills, and storerooms for various purposes. It is extremely unlikely, therefore, that many artists will be in possession of such premises and plant. It follows then that he must, as a rule, consign his larger works to one of the commercial foundries for execution. Nor is there any very great hardship in this. It is in such cases only requisite that the great lines and masses should be faithfully reproduced. Any delicacy of touch that might be put into such a work would be useless, because it could not be seen, and, therefore, would not be missed in the casting.

It occasionally does happen, however, that such premises as I have described are at the artist's disposal, and in this case the best work is certainly expected of him. Such a case was that of my old master, the late Chevalier Louis Jéhotte, of Brussels, in whose studio and foundry I gained my first practical knowledge of artistic bronze work, more than twenty years ago. The foundry was such a one as I have described, and the work in hand was the casting of the equestrian monument to Charlemagne, which was subsequently erected at Liège.

Now there are two principles whereby artistic bronzes may be produced. The one is that known as piece moulding, and is identically the same as that employed in making castings for machinery, etc. Continental artists and founders call it *moulage à la Française*, it having been brought to great perfection in France, where, indeed, it is supposed to have had its origin.

The other process is that known as "Cera Perduta," or waste wax process. It is the most ancient of the two, and has been practiced from time immemorial by the artists and artisans of Italy.

Both methods have been and are successfully employed for the production of works of the greatest size. M. Jéhotte, however, decided, and all my late experience convinces me he was right, in favor, of the *moulage à la Française*.

It may be well here to state the reasons why an artist should sometimes prefer one method and sometimes another. When a piece of sculpture is to be produced on a very large scale, it is usual for the artist to make not only a careful sketch, but also, if he has a proper regard for his own reputation, he will make a model of a convenient size, usually about life size; and on this model he will bestow all his skill and art, taking into account the distance at which the colossal work will have to be viewed, its height above the level of the spectator, the effect of the atmosphere in diminishing its apparent bulk, and in distorting its lines, the influence of any surrounding objects, and more especially the varying effects of light and shade. When this model has been carefully completed, the work is then to be reproduced in all its details on the large scale. One pair of hands will not suffice for the production of so large a work, and several assistants are usually employed, under the supervision and control of the master, who, working with them, is thus able to produce what is practically an exact enlargement of his smaller model.

Works on a colossal scale cannot be produced by the eye alone, but must be the result of scientific procedure. The forms are so large that the workman cannot see the effect of what he is doing. If he has to descend from a scaffold ten or twelve feet high, and go perhaps fifty or sixty feet off, before he can get a comprehensive view, it is not likely that he will be able to correct any error which his eye may have discovered, because by the time he has again ascended the scaffold he can no longer recognize the exact spot that required alteration.

In these large works anything like individuality of touch is at a discount, surface modeling is practically useless, and artistic effect is alone realized by the rhythm of line, the harmony of proportion, by the skillful arrangement of masses of shadow, and by the true relation of each plane to the rest of the work. If this is achieved, the result will be an artistic success, not to be enhanced by any amount of delicate manipulation, which would be entirely lost at the distance required for a comprehensive view of the work. It is, therefore, wise in the artist to select that method of casting which, while it faithfully reproduces these essential qualities, affords the least chance of mishap, and the greater facility for retrieving disaster.

The artist who enters on the production of a very colossal work is in the position of a general opening a campaign. He forms his plan, and lays down broadly the lines on which he intends to proceed; but he cannot foresee all the chances of war, nor the varying incidents which may oblige him to modify his plans if he would attain the reward of his labor.

Thus it is clear that for such works there is no system of founding so good as that which gives most scope to the founder, even if it were at the sacrifice of a very small degree of sharpness in the castings.

With regard to small works, however, the case is very different; and exactly in proportion as these are small does the importance of delicate touch and surface modeling increase, not that the other qualities I have just spoken of are diminished in value, for they are just as important as ever, but merely from the fact that the eye of the spectator is able to take in on the small scale that which it was unable to appreciate on the large. Many persons who are unaccustomed to look at sculpture intelligently, and who think that art means pictures alone, would be surprised to learn that there was any difference between the touch of one sculptor and the handling of another. For such persons a work is finished in proportion as its surface presents a polished uniformity. This idea is fostered by the miserable cabinet bronzes which are turned out wholesale by certain manufacturers, and are termed "art bronzes." These are often copies of fine originals, but most of their value is lost from the fact that they are cast in many pieces, which are then joined together, filed, and chased up in a happy-go-lucky commercial style by a not over skillful artisan. Thus every trace of the original hand is obliterated, all that remains is the design, and even with that liberties are often taken. The turn of a head, the movement of an arm, are often varied according to the convenience or ignorance of the fitter. Yet, such as they are, these *soi disant* "art" bronzes are replicated *ad nauseam*, and do duty as sculpture in the homes of the wealthy and well-to-do classes, who, I venture, however, to predict, will, before many years are over, be as keenly alive to the merits of a bronze as they are already to those of a picture.

It will be an unspeakable comfort when these purely commercial productions shall be estimated at their proper value, and be relegated to the possession of those whose purses are too slender for the purchase of original works. These can only be produced by the wax process, and by the artist himself, or at least under his own immediate care and supervision. I propose now to explain to you, as clearly and briefly as I can, the method of casting statues in the ordinary way by piece moulding, or, as I told you it was called, *à la Française*. I shall then explain to you, as fully as time will permit, the other or *cera perdula* waste wax process, more especially in regard to its applicability to work of cabinet size.

The object of casting statues in bronze by piece moulding is to diminish the risk by facilitating the process. It is obviously easier to cast a part than the whole of a statue. This is the principle which underlies commercial castings. You will follow me more easily if I give you an illustration. I have chosen as the subject of this illustration one of my own works, modeled in Rome many years ago, and cast in bronze by one of the most celebrated founders in Paris from a plaster cast which was carefully retouched by myself before it was delivered to the founder. You will perceive that the figure, which represents Divine Wisdom, stands on a tortoise surrounded by waves, and supported by a branch of coral. The first operation of the founder was to cut off the head and arms of the plaster model, and also the coral branch at its side. These were carefully replaced, being fitted with what are known in our profession as Roman or box joints. These joints, if properly made, insure in the most effectual manner that the various parts shall not be misplaced in any degree whatever.

The plaster model thus became a compound of five separate parts, fitted accurately one to the other. This made the work of the founder much more easy and rapid. To mould and cast the head, the arms, and coral branch, each by itself, is so simple an operation that almost any lad in the foundry could be intrusted with it; but to cast the statue all in one piece would have entailed some rather complicated piece moulding. When denuded of its head, arms, and coral branch, the trunk is also a comparatively simple object to mould. I say comparatively because there is in the folds of the drapery a great deal of piece moulding which requires care and skill. I cannot here go into every detail of the process, which, however, was briefly as follows: The trunk of the figure was laid in an iron box or flask of suitable size, and loosely packed in with the loam used by bronze founders. The figure being only about half embedded in this loam, the surface of which is carefully pressed and smoothed all around the model so that the latter presents somewhat the appearance of a bass-relief. The loam background, as I may call it, is then lightly and evenly powdered over with parting-dust, lycopodium being much used for this purpose on the Continent. The object of this is to prevent one portion of the mould from adhering to another.

The moulder then proceeds to work on the projecting portions of the model, making separate pieces, so that they can be withdrawn and replaced at will. When he has made as many pieces as his judgment tells him are requisite, he places another iron box or flask upon the first, and having applied the parting-dust to the work, he makes of the same loam the cope or case which is to retain all the pieces of the mould in position, and which is itself held together by the flask, which is merely an open iron frame. The two flasks are then turned over, and the first flask with its loosely packed loam having been removed, the freshly exposed side is moulded in the same manner as the former, and the cope or case formed as before. The two flasks can now be separated, and the pieces of the mould removed one by one from the figure, and accurately replaced in the mould. This gives a correct imprint of the plaster model. If the metal were cast into this, it would be quite solid, therefore it must be cored. The core is made by filling the cavity of the mould with the same loam, so that the figure is again reproduced. As, however, this loam figure occupied the entire cavity of the mould, it must be pared down so that an empty space may remain between its surface and the interior of the mould. This space is that which will be occupied by the metal.

Of course, such a core has to be supported by an internal iron framework, the ends of which, projecting through the openings of the neck, the arms, and at the base, serve to keep it in position; without this it would of course fall to one or other side, and thus prevent the flow of the metal.

Openings must be provided in the mould for the admission of the metal and for the escape of the air; but as we are rather considering principles than matters of technical detail, I shall not trouble you with the description of these at present, merely remarking that the vents for the air need not be so carefully arranged in casting on this system as in casting by waste wax, because the loam is very porous, and the joints in the mould facilitate the escape of the gases. By this process the risk in casting a statue is reduced to a minimum—no small advantage where colossal work is concerned. Nevertheless, when the bronze is cleaned from the loam, it will be found to be covered with lines from the joints of the mould; it is also not unlikely to be covered with a sort of hard skin, composed of particles of sand, which have been vitrified by the intense heat. This skin and these lines have to be removed, and the various parts of the figures must be joined together. It is very frequently found necessary to go over the entire figure with the file and chasing tool to bring the work to one tone, and in that case it is not possible for the statue to retain any claim to be considered an autograph work. There can remain on it no touch of the original artist, and the fact of his signing it, and even numbering and dating it, will not save it from being merely a more or less excellent copy and not an original.

Of course, if a sculptor chose to do the chasing and fitting himself he could do so, but think of the waste of time, not to mention the fact that even then the work would probably lose something of its original freshness and spirit.

This system of piece moulding from bronze is admirable for commercial purposes, and for colossal work it is all that can be desired, but otherwise its value is small, and I do not hesitate to say that a statue executed by this method cannot be esteemed by any one who understands sculpture at more than a fraction of the price of the same statue if cast by the waste wax process.

It is this waste wax process, so unimportant commercially, so all important artistically, to which I am about to call your attention. It is by this method alone that a sculptor can produce original bronzes in his own studio, without the drawbacks incidental to the former process of piece moulding.

Roughly speaking, this process is as follows: The sculptor makes, of plastic wax, an exact model of the work which he desires to cast in bronze. This model must be hollow, the thickness of the wax being exactly that intended for the bronze. This wax model is to be moulded, both inside and outside. The mould must be all in one piece, and without seams. The wax, therefore, cannot be withdrawn without destruction either to itself or to the mould. But as the mould must be preserved till after the bronze is cast, the wax is withdrawn by melting it out. The bronze is then to be poured into the cavity.

Of course, this is not so simple as it sounds, and yet I hope to show that there is nothing in it that may not be successfully carried out by an artist in his own studio. I am speaking now exclusively of small works, that is to say, of works under life-size.

The first thing that claims our attention is the wax. This must be made harder for summer weather, and softer for winter use, unless, indeed, the artist is careful to keep his studio always at one temperature. This seems a small matter, but, nevertheless, it is of great importance, and much of one's comfort in working depends on it.

There are many different wax compositions, almost every founder having his favorite mixture. The chief ingredients, however, are beeswax and Venice turpentine. Some artists make use of no other ingredients and use no coloring matter. Most men, however, use, in addition to the above, resin, lard, tallow, and pitch in varying quantities. I have made excellent wax either with or without these latter. Yellow wax is not easy to model in. It is therefore the general practice to stain it, in order to get rid of some of its transparency. In Italy, it is almost always colored a brilliant red, with sulphide of mercury, which is entirely evaporated when the wax is melted out, and leaves no residue in the moulds. Almost any pure vegetable color will do, or indeed any other that will burn without leaving a residue; this is easily tested by placing a lump of the wax in a small white clay crucible, closing the top with a cover, to prevent any dirt getting in, and then burning away the wax. When the wax appears to have been consumed, you should gradually raise the temperature to a cherry-red heat, and then let it cool down. If, when the crucible is quite cool, you find it also quite clean, without any residue, you may be sure that your wax is good, and that the pigment used is perfectly safe.

Having, therefore, prepared the wax, and having satisfied himself that it is of the right quality,

the artist will proceed to construct his model. He could make this at once in wax, and then cast it, but in event of a failure his work would be lost. As this is undesirable, he usually proceeds exactly as if the work were to be sent to a foundry, and having prepared his plaster model, he cuts it in pieces and moulds it in plaster, making safe moulds of each part. From these moulds the hollow wax models are produced. Of course, it is far better for the artist himself to retouch these than that they should be so treated by any other person.

There are various ways of producing these wax models. Some artists cast them by pouring the melted wax into the mould, in which a core has been previously placed; others line out the mould by squeezing into it sheets of wax that have been prepared so that they easily take the required impress. Others, again, brush the liquid wax into the various parts of the mould, and having thus satisfied themselves that the surface is everywhere covered with a thin layer, they put

FIG. 1.—SIMPLE CLOSE WASTE MOULD.

the mould together, and fill it with melted wax, which, after a few seconds, is emptied out, leaving, however, an equal layer adhereing to the former coat. This operation may be repeated as often as desirable; each time increases the thickness of the wax, and consequently of the bronze. Making the wax casts sounds a simple matter, and yet it is almost the most difficult thing connected with the waste wax process.

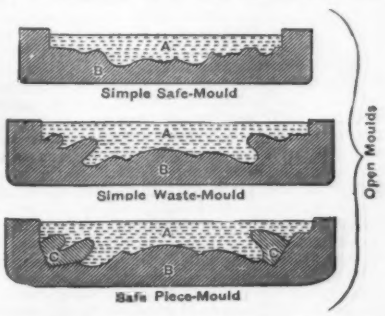
In Italy, where this system is much practiced, nearly every *formatore* can get out good casts, but here it is different, and the sculptor will probably have to train his moulder. It is merely knack and practice, and any intelligent moulder will soon get into the way of it.

It is not the extreme sharpness of the impression that seems to me so very important, though that of course counts for something; but I generally prefer to work my waxes entirely over, and instead of merely retouching, to finish the work in the wax. It is the inside of the wax cast that is very important, because it should have a proper thickness of wax in every part, no more and no less. It is safe, however, to have rather a too heavy than too light a cast, as there is no vitreous skin formed by a thick casting, as is usually the case when the piece mould system is employed.

The various parts which compose the figure having been prepared in wax, it is the part of the artist to join them together and finish the work in wax exactly as he wishes that it should appear in bronze. The wax being hollow, must be moulded or cored on the inside.

If the work is a very small one, say eighteen inches high, he may finish the wax first, and then put a few wires through it at various points which serve to keep the core in place; he can then pour the liquid core into the wax model, which will be strong enough to resist the pressure during the few moments required for the material to solidify.

If, however, the work is much larger, the wax will not have the strength to support its own weight, much less the internal pressure of the core. In such a case it is requisite that the core be cast before removing the wax model from its mould. The plaster safe mould must in this case be so constructed that it can receive and hold in place the irons which support the core and retain it in position. For this purpose holes must be



A, the cast; B, the cope or case of mould; C, the loose pieces of mould.

FIG. 2.

made through the walls of the safe mould to permit the irons to project. They must afterward be held by the walls of the waste mould in which the bronze is to be cast.

The safe mould, then, being lined to a proper thickness with wax, and having the core irons in position, is to be filled up with the liquid composition used for coring. The usual mixture is plaster and brickdust. Some people use other ingredients, indeed I have a list of over five and twenty which have all been used for this purpose. The proportions used are very various, some persons recommending one-third brickdust and two-thirds plaster; and others, three-fourths brickdust to one-fourth plaster. The truth is that these materials vary so much in their character that those proportions which are quite satisfactory in one locality are worthless in another. I beiieve, however, that it is best to use as little plaster as will suffice to bind the materials together.

The core, being surrounded by liquid bronze, is under conditions exactly opposite to those of the mould which contains the metal. The action of the metal is exerted

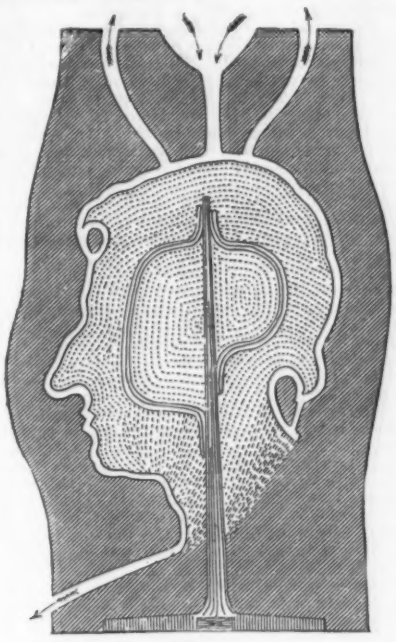


FIG. 3.—DESCENDING PROCESS.

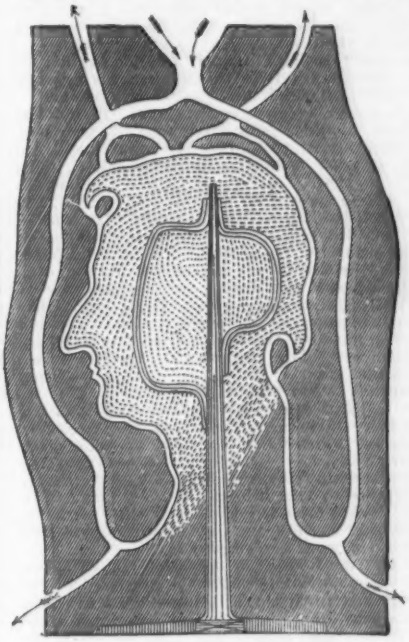


FIG. 4.—ASCENDING PROCESS.

to compress the core and to burst the mould. Moreover, its greatest bursting power is exerted while it is in a state of perfect fluidity, and on setting it contracts, relieving the pressure on the mould, and powerfully compressing the core. If the core is too hard and unyielding, it is certain to crack the bronze. It should be what is technically called "puffy"—that is to say, somewhat easily compressible; on the other hand, unless it has some ventilation to the outer air, it should not be too porous, or it will generate gas too rapidly by contact with the hot metal. In cores of considerable size it is always safest—indeed, necessary—to provide some means of escape for these gases by venting the core.

When such a vent or "lantern" is used, the core can be made more spongy, and consequently more readily yielding to the compression of the cooling metal. It is, however, a fact that, while modern practice amply justifies the use of a core vent or lantern, the largest works cast by this method of which we have any historical record—such as the colossal equestrian statues of Louis XIV., by Girardon, Louis XV., by Bouchardon, and the Henri IV. on the Pont Neûf at Paris, by Lemot—were all successfully cast without any such precaution, nor can I find any mention of such a practice before the latter half of the present century.

The wax model with the core inside can be kept for an indefinite time, and thus the artist has ample opportunity to work on the wax, and bring it to as high a degree of perfection as his talents will permit. When, however, he desires to cast it, his first care must be the arrangement of the jets and vents. The jets are tubes destined to distribute the metal throughout the cavity of the mould, and the vents are other tubes which afford an exit to the air violently expanded and displaced by the molten bronze. The jets are comparatively unimportant, for the bronze, following the laws of fluids, will certainly fill every part of the mould, provided the air offers no obstacle to its progress.

It is, therefore, usual to have more vents than jets, and they should be so placed that wherever there is a bell or pocket formed by the configuration of the mould in which the air might be imprisoned, there must also be a vent provided for its escape. It may seem strange, but I believe it is a fact that greater attention is needed in this respect in small than in larger works, because in a large work the metal does not set so rapidly, and thus gives time for the air to escape into the pores of the mould, while the pressure to do so is much greater. In any case the labor of placing these jets and vents is but small, and as their importance is paramount, my advice always will be, "When in doubt, put a vent—put a dozen rather than run even a small risk."

I said just now that the piece-moulding in loam did not require the same attention in this particular, as the joints in the mould acted as a complete network of vents. This would seem a very great advantage over the wax process, and so it would be were it not that the method of placing these jets and vents is so easy and simple that it involves but little skill, and is easily done by an assistant. The artist need not lose his time over it, beyond defining their positions and relative sizes.

The jets and vents, being merely a system of tubes leading from the outside of the mould to its inner cavity, become of course filled with metal, which remains as solid rods attached at one end, while the other end is free in the air. All that is therefore needed is to make rods of wax of the required size, and attaching them by one end in their proper position on the surface of the work, bend them into the required curves. As, however, it would be inconvenient to pour through more than one jet, it is usual to join them together in groups, and to bring these again together to one main jet, which leads directly from the basin, or "sow," into which the bronze is poured. By this means, the bronze flows from the main jet through all the subsidiary ones to the different parts of the mould.

The vents are treated in exactly the same manner, except that they do not usually end in one main duct, but in several, as may be most convenient, nor do they rise to the basin, but come to the open air at the top of the mould, outside of the space occupied by the pouring basin.

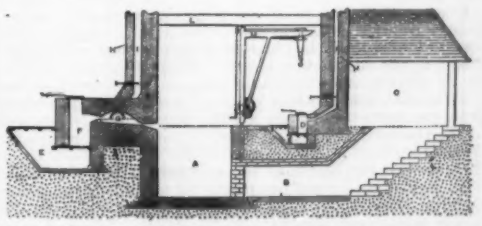
Besides the jets and vents there are other rods of wax which are called drains or spouts; these are placed on the lowest portion of the work, and lead through the thickness of the mould, but slanting a little downward to the open air. Their object is to drain away the wax where it is melted out, after which they have to be securely stoppered up. In very small works drains are entirely omitted, and the mould is merely turned upside down to allow the wax to run out.

There are two principles of pouring bronze, each of which has its advocates. The one is the descending and the other the ascending principle. In the former the bronze is cast directly into the cavity from above, as shown on Fig. 3, which is not designed to represent any particular work, but merely to illustrate a principle. By this method the bronze enters through all the various jets, and gradually fills the mould until it reaches the top. In the second or ascending principle, as shown on Fig. 4, the jets are taken right down to the bottom of the mould before they are allowed to enter its cavity. The metal of course rises to its own level, thus filling the mould from the bottom.

We do not know when the ascending principle was invented, we only know that it must of necessity be more recent than the direct descending method; but we do know that the ascending principle was employed by Michel Angelo for the second casting of his statue of Julius, and there is some reason to believe that Cellini employed it to cast his Perseus, but of this I am not certain.

The great monuments of Louis XV. at Bordeaux and of Louis XIV. at Paris were certainly cast on the descending principle, while Bouchardon cast Louis XV., and Falconet his Peter the Great, by the ascending method.

The disadvantages of the descending or direct method are these: When the bronze is cast, it flows directly into the mould in numerous streams, which trickle over the core and over the surface of the mould, making a great amount of atmospheric disturbance in the cavity. These streams unite at the bottom, and then the mould begins to fill after the air contained in it has been heated and expanded to the utmost; nay, it is more than probable that portions of air caught between two metal streams may be dragged along and forced to escape by bubbling upward through the molten metal, causing the latter to boil and work, and thereby endangering the delicate and frail inner surface of the mould. Moreover, the streams of metal, having united at the bottom, must rise and pass again over the sur-



A, pit; B, entrance to pit; C, shed or store over stairway; D, crucible furnace; E, ashpit with gratings; F, fire-box of reverberator; G, hearth of reverberator; H, chimneys; I, flues; K, wall of foundry; L, cross beam; M, foundry crane.

FIG. 5.—IMAGINARY SECTION OF STATUE FOUNDRY.

face of the mould before it can be completely filled. I do not know any objection to the ascending principle. There the streams of metal pass harmlessly to their lowest level before entering the cavity of the mould; thus its surface cannot be injured by the downward rush, and the air is not brought in contact with the metal until it begins to rise in the mould. No particle of air can become entrapped, for it is all above the surface of the rising bronze, with a free exit through all the vents above, through which it is forced by the

pressure of the rising bronze, and by its own enormous expansion, which, however, cannot be so great or so sudden as when the metal enters from above. I should, therefore, recommend the artist always to cast his works on the ascending principle. The jets and vents having been arranged with due consideration, as I have described, it becomes necessary to think of the mould, and to consider the qualities to be sought for in a mould for bronze casting. In the first place, the material used must be one that is easy of application, and of a nature to resist the intense heat to which it must of necessity be subjected. It must also not be antagonistic to the metal, which would otherwise be spurted violently from the jets and vents, besides which it would certainly yield a blunt and bad impression.

There are many recipes for such moulds extant; almost every one who practices this art has his favorite mixture, concerning which much secrecy is observed.

There is, however, no great secret about this matter. Many of these moulds, especially those of large size, which, of course, have to endure the most heat, are made of *luto* or *polée*, as it is indifferently called. This is nothing more than a mixture of which the basis is fine loam. The loam may be natural or artificial; the whole secret consists in purifying it sufficiently, and in grinding it very fine before use. The materials mixed with it are fire-clay burnt and ground to an impalpable powder, emery, rotten-stone, hammerscale, etc., etc., the only object being to obtain a very fine and fire-resisting powder. Old crucibles powdered up are highly recommended by no less an authority than Cellini. Some material has also to be used that will bind this powder together. The celebrated founder Jean Balthazar Keller used white of egg and horse-dung. Cellini preferred rotten rags and cow-dung. The result sought for and attained in either case was the same. The body of the mould was composed of a very fine fire-resisting powder, held together by some other less refractory body, the result of which was that the mould, when tolerably dry, was firm and solid enough, but when exposed to a great heat it became very friable and porous. These moulds took a long time to make, but the operation was not one that required great skill on the part of the workmen employed.

This was the method of construction: A sufficient quantity of the material having been prepared of the requisite degree of purity and firmness, a small quantity of it was placed in a mortar, and ground up until it became of the smoothness and consistency of oil paint. Armed with a soft bristle brush, and with a pot of this paint, if I may so call it, the assistant proceeded to give the work one complete coat—an even, thin coat, just as if he wished to color it. This is allowed time to dry, when, if it has been laid on thinly and evenly, it will be found to have dried without a crack. A second coat is now laid on in the same way, and with the same care, as thinly as possible. This is again allowed to dry, and so on for about thirty coats. After the first five or six coats, however, a portion of cow-hair may be worked into the paint, and it may be spread a little thicker. After about thirty coats have been given, there will be a thickness of about three-quarters of an inch, and the mould may now be completed by building up in thicker layers until a sufficient strength is obtained. The mould must be hooped about in all directions with iron bands to strengthen it. After this, it being apparently pretty dry, a temporary kiln is to be built round it, and a gentle fire is kept up until the wax flows out through the drains before mentioned. A considerable quantity of wax will be lost, but some of it may be saved by placing tubes at the drains to lead it outside the kiln. This operation is usually, but not invariably, conducted in the pit beneath where the metal is to be melted.

When the wax has ceased to run, the fire must be let out, and the kiln taken down, in order that the drains may be stopped. These must be plugged with great care with the same material used for the mould; the kiln is then built up again, and the firing carried on as before, until the wax has been completely dissipated. When there seems to be no trace of wax left, the fire must be still kept up, and indeed urged on, until the mould and core are both of a fine cherry red, after which the fire may be let out, and the whole allowed to cool slowly down. If the mould is at the right heat, it can be seen on looking down the openings of the vents and jets, or on putting a piece of tarred rope down, when it will take fire if the heat is right.

The kiln being cool enough, it must be pulled down, and the pit must be filled up with fine dry earth, pressed firmly and evenly all round the mould, so that the top alone, showing the openings of the jets and vents, is visible above the ground. Be the work small or large, this process of firing is exactly the same, only that a mould for a very small figure can be fired in about eight hours, and the statue of Louis XV. took five weeks.

For small works, however, it is not advisable to use a *luto* mould. Compo is quite good enough. By compo I mean any mixture of which plaster and brick-dust are the chief components. Many founders use for the moulds exactly the same composition that they use for the core, and it saves trouble to do so. It is better practice, however, to use a somewhat stronger compo for the mould. Some persons make an inner skin to their moulds of a closer and harder composition than they use for the backing up, and this is in accordance with theory and good practice. It requires care, however, as, unless the heat is carefully regulated, these layers sometimes separate in the firing. We will suppose, however, that the work has been successfully fired, and is in the pit earthed up and ready to cast.

Our next consideration is the furnace. This may be made in many different forms. Only three, however, need be mentioned at present.

First in power and capacity is the reverberatory furnace, with its saucer-shaped hearth and its flat domed roof. It may be made of every varying size, but it is inconvenient when made for small charges. These furnaces are a very ancient invention, but until the end of last century they were made without any chimney, the draught being supplied through two or three long trenches, with the aid of wind-sails. Modern practice has dispensed with these last, and added a tall chimney, besides flattening the dome of the roof very considerably.

The furnace most suited for small works in the artist's studio is, however, the common air-furnace for crucibles. This furnace is cheap and easy to build, and takes up but little room. It is usual to build a row of them in the form of a low wall along one end of the workshop. The usual size takes a crucible with a charge of about 40 lb. to 60 lb. of metal; this is easily lifted out by one man. If more metal is required, several crucibles are poured at once. These furnaces are, however, sometimes made of much greater size, and crucibles are used which will take 1,000 lb. of metal; but these, of course, are not likely to be used by artists very frequently.

Another kind of furnace which is very convenient is the portable furnace made by Messrs. Morgan, of Battersea. It is exactly suited for artists' occasional use, and will take a charge of 32 lb., quite enough for a small bust, or a sketch, or statuette.

The metal most suitable for artistic work is an alloy of copper and tin, either with or without the addition of zinc, lead, or both. The mixture used by the Kellers was, copper, 91·4; zinc, 5·53; tin, 1·7; lead, 1·37. Copper, 87·8; zinc, 6·52; tin, 5·1; lead, 0·58; gives also a very good metal, used for the Henri IV. Copper 93, tin 7 parts, gives an excellent bronze. An equal quantity of yellow brass mixed with this gives an excellent and easy-flowing metal. The bronze is usually considered to be improved in color by using zinc, and lead is supposed to aid it greatly in flowing. The tin gives great hardness, and when the amount of tin used is over 20 per cent., the metal becomes useless for artistic purposes.

I am personally inclined to give the preference to a bronze composed of copper and tin alone, and 3 or 4 per cent. of tin gives an excellent and beautifully red metal. This alloy, however, when used in small quantities, is apt to prove rather sluggish, and requires more nice management as to the degree of heat than those alloys which contain a considerable amount of zinc or lead.

The operation of firing is a very simple one; and if the crucibles used are those known as the Salamander brand, there are no precautions to be observed. The crucible stand is placed on the bars at the bottom of the empty furnace. The height of this stand should be such as to bring the top of the crucible a couple of inches below the throat of the furnace. The stand should have a thin layer of ashes on it, to prevent the crucible sticking to it. Then put in as much metal as the crucible will contain, and cover it over with a proper cover; throw two or three shovelfuls of live coke into the furnace, and fill up all round your crucible with good clear broken coke up to the level of the crucible top. Place some large pieces of coke on top, taking care that they do not get in the throat of the furnace, and so choke the draught. Put on the cover of your furnace and draw out the damper, and fire as hard as you can until you find that the metal has run; then add more and more by degrees until you have a full charge. Some people keep a thick layer of charcoal dust on top of the metal, others do not take any precaution to prevent the formation of dross. Most persons, however, add a little borax, which powerfully cleanses the metal. It must be well skimmed off before pouring.

When the metal is ready to be withdrawn from the furnace, the coke must be cleared away from the pot, so as to make room for the crucible tongs. These are placed over the pot, and kept closed by a ring. The pot is then lifted vertically by one or by two men, and if it is a small one it is poured at once out of the tongs, but if it is a large one it is placed in a receptacle called a cradle, which is carried by two or more men. Sometimes it is poured into a hand ladle, or shank, and thence into the mould. This is not, however, usually done unless the contents of several crucibles is required, and then it is better to form a large basin, or core, at the top of the mould, the openings of the jets being closed with plugs. All the crucibles should be poured into this basin before drawing the plug; this insures a clean casting, as all impurities float on the surface, and are not carried into the mould. When this basin is not used, it is of the utmost importance that the bronze should be thoroughly skimmed. If the metal runs down quietly, and rises up in the vents till it reaches the surface, it is a sure sign that the mould has filled properly. If, on the other hand, it makes much noise, and, worst of all, if it spurts and sputters in going down, and does not rise up again in the vents, it is certain that the casting is a failure.

The moulds for small—indeed, for all—work should be broken down as soon as practicable after the metal has set, but great care must be used not to expose the surface of the casting too soon, for while it is red hot bronze is extremely fragile and liable to injury. The statue, on being freed from its mould, will be found with its system of jets and vents perfect as they were made in wax. These are then to be cut off with a saw as near as convenient to the surface of the statue. The figure is then to be well brushed with wire brushes, to remove all the particles of the mould; it is then placed in a bath of very dilute acid to pickle, as it is called. This cleans the surface of the metal very completely, and the artist can then repair any little defect that remains, as, for instance, the places where the jets have been and the like, after which it is usual to give the work its patina or color.

It would be quite impossible for me to go into the subject of patinas this evening. It will suffice to say that the color is produced by the action of various salts and acids on the surface of the bronze. A great variety of tints are obtainable, and in the selection of these every artist will, of course, exercise his own taste and judgment.

Although there are, both in England and abroad, excellent statue founders, whose work leaves nothing to be desired as far as the ordinary run of bronze work is concerned; and who are even able to go considerably beyond the average requirements of commercial sculpture, yet it has always seemed to me to be a matter of deep regret that autograph work in bronze is almost non-existent in England at the present time. Sculptors used, even in this country, to be their own bronze founders, and that at no very distant date. Chantrey cast his own works, and more than one sculptor's studio in London was arranged for casting statues of considerable size. The late Baron Marochetti was, I believe, the last sculptor who cast works in this country, although, only five or six years ago, a very nice statue foundry in the studio of the late Mr. Weekes was pulled down and converted into livery stables.

If artists could be persuaded to become once more their own founders, as far, at least, as small works are concerned, I do not think that it would be a matter for regret even to the manufacturers of cabinet bronzes. These would still command a large sale, as the autograph works produced by artists would of necessity be higher in price and few in number. I fear that it may be objected that bronze casting is not an artistic but a mechanical employment. Against this view of the case I must earnestly protest, as my own experience is that bronze casting requires quite as much artistic skill as marble carving, and that neither the one nor the other should be in other hands than the artist's own. Do not understand me as in any degree objecting to the employment of assistants in art, more especially in sculpture. I only protest against the practice of so important a process as bronze casting being left entirely in their hands.

It is, I fear, a great cause of reproach to modern sculptors that comparatively few of us are thoroughly and practically conversant with the various processes employed in our own profession.

It is no less a matter of regret that, in the various art educational establishments in this country, the student of sculpture is merely taught drawing and modeling, but is unable to learn the other processes whereby alone his modeled work can be rendered permanent. He is not only obliged to employ others to undertake this work, but he is absolutely unable to direct or to instruct them. He is, in short, at the mercy of his assistants until years of dearly bought experience have enabled him to pick up for himself what is, after all, but the A B C of his profession, but which, unluckily for him, no school of art in England teaches.

There is, perhaps, one remedy for this—namely, the possible establishment of studios in connection with our national art schools, where the student of sculpture could be practically taught the various processes incidental to his profession, such as piece and waste moulding, marble pointing, enlarging and reducing, carving, bronze casting, the erection and construction of colossal work, etc.

A year or two spent in such a studio in the study of practical sculpture would be invaluable to the student, and would enable English sculptors not only to instruct and guide their own workmen, but also, in course of time, to obtain competent English assistants, instead of being forced, as is at present too frequently the case, to employ foreign workmen. It would also enable artists to execute their own works in any material, and with their own hands, whenever desirable.

I know that, for many years past, the English public has taken little or no interest in sculpture; but, unless I am mistaken, indications are not wanting to prove that there will, ere long, be a considerable change in this respect, and that sculptors will find it greatly to their own advantage to remember that they are artists, and not, as is too often the case, mere manufacturers.

In conclusion, let me once more insist on the inestimable value of autograph work, more especially for bronzes of small size. Unless these are really produced by the artist himself, and bear the palpable impress of his own mind and hand, unimpaired by foreign touch, and perfect throughout in character and individuality, I am really unable to see what value they can possess beyond that of a skillfully executed copy, nor can I admit their claims, in spite of date and signature, to be considered as genuine autograph works.

ROMAN CARPENTRY.

Professor HOSKING.

THE arch not only superseded the use of long stone beams, but was constantly used in places where indeed joists of wood would been have much more convenient, giving support to the opinion that even the Romans were not skilled in the application of timber to their edifices, though, on the contrary, it is difficult to understand how Rome could become subject to such a dreadful conflagration as that which occurred in the reign of Nero, if timber had not been employed in the ordinary houses of the city to a much greater extent than would appear from existing remains. The domestic structures of Herculaneum and Pompeii were evidently never very susceptible of fire, from the small quantity of timber required in their construction; and discoveries which are made from time to time of portions of the ordinary houses of ancient Rome under the pavements of the modern city evince that they were very similar to them in almost every particular. The infrequency of stairs, and the meanness of those which exist leading to upper apartments in the houses of those cities, leads to the belief that the Romans seldom built above the ground story, and that their skill in carpentry was not very great, otherwise they would more frequently have had recourse to so easy and convenient a mode of extending room as upper stories offer.

There are, however, other things which tend to prove that carpentry was well understood by the Romans; and the most remarkable is the bridge that Trajan built over the Danube, the piers of which are said by Dion Cassius to have been 150 feet high and 170 feet apart. Now, whether the bridge itself consisted of a wooden platform, as there is much reason to believe, or was of stone arches, as the historian intimates, the skill which constructed centering for the latter, or laid the platform from pier to pier in the former case of that immense extent, was amazing; nevertheless, such skill in carpentry is not evinced by the remains of the civic and domestic structures of the Romans, in which arching in all its varieties was used where carpentry would have been better. Of their joinery we know nothing; but it does not appear, from the last quoted mode of ascertaining such things, to have been much practiced by them, mosaic pavements supplying the place of flooring, and stucco that of wainscoting; the luxury of windows being unknown, their fittings were not required, and doors, it would appear, were uncommon, except externally, the internal doorways being probably covered with something equivalent to the quilted leather mats suspended from the lintel which are used instead of swinging doors at the entrances of the churches in Italy at the present time.—*The Architect.*

FOR good bold labels for stock bottles the *Journ. de Ph. d'Als.-Lorr.* recommends a paint made from 10 parts of liquid silicate of soda (soluble glass) and 1 part of common oxide of zinc. Three or four layers of this paint to form the white ground, the letters to be marked on with coal-tar diluted with a little turpentine.—*Chemist and Druggist.*

HARLOW VICARAGE, ESSEX.

THIS vicarage is now in course of erection, and is being built with Stanstead red bricks with white brick bands, box-stone heads and sills, and terra cotta strings, etc. It contains four sitting rooms, nine bed rooms, and the usual offices. The architects are Messrs. Weaver and Adye, of Devizes and Bradford, Wilts; and the builder is Mr. William Wade, of St. Neot's, Huntingdonshire, whose contract is for £1,900.—*B. & E. Times.*

ARTIFICIAL GEMS.

By HERMAN REINBOLD.

THE manufacture of artificial gems has in the last twenty years become of very great importance, and the progress of chemistry has given us the possibility to produce gems artificially which, in their hardness, composition, luster, and brilliancy are almost equal to those found in nature, diamonds excepted. Most of the artificial stones or gems are manufactured in Paris and in some places in Germany, and of course pay very well. It is only a very few years ago that all the so-called artificial gems were simply colored glass, underlaid with silver or amalgam; but as we know now the real chemical combination of the gems, experiments led to exact imitations.

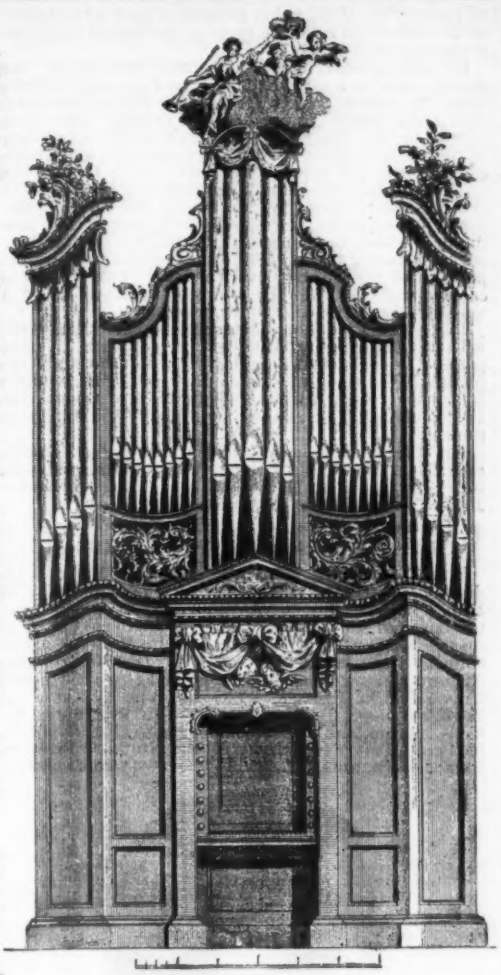
As the manufacture of these gems is not very well known in this country, and every manufacturing jeweler is able to make them at a small expense, a few reliable formulas will probably be gladly accepted. Of the gems, ruby, sapphire, emerald, and diamond are the most important, and to-day it is even for an expert very difficult to tell the difference of a genuine ruby, emerald, or sapphire from one made after the latest discoveries in chemistry.

The principal proof of the genuineness of the gems is the hardness, but even this has been imitated lately to such a degree with several of the artificial stones that this is not a proof any more.

In making artificial gems the purity of the chemicals smelted together, as well as the cutting of the stone, are of the greatest importance, and by this the brilliancy, luster, hardness, the light reflecting properties and transparency of the genuine gem are almost reached.

SAPPHIRE.

The chemical analysis has proved that the sapphire is pure alumina, or oxide of aluminum (Al_2O_3). This mineral is very abundant; and is found as a white powder, of great hardness, and can be smelted only in the highest temperature. By this the blue color of the sapphire is not explained, which, as it was formerly believed, was due to certain chemical and optical properties of the mineral. As it is known, the sapphire has that special property which is called dichroism, that is, to shine in two different colors, blue and red. In a well cut sapphire often appears a red cross in the blue stone. This property, which is the same in the ruby as well as in the sapphire, and for which no satisfactory explanation has been found yet, has been reproduced lately by the French chemist Sidot accidentally. As alumina has no color, and both sapphire and ruby show the same optical properties, the problem has been solved, and the above-named chemist after some experiments made stones artificially, which show exactly the same optical property of dichroism.



DESIGN FOR A VILLAGE CHURCH ORGAN, BY CHIPPENDALE.

An iron pot is heated to dark red heat, and in this 4 oz. superphosphate of lime is put and brought to the same heat, while it is stirred with an iron rod. (Superphosphate of lime is used very extensively as a fertilizer, but can be made artificially from bones by treating burned bone ashes with sulphuric acid.) By this process the superphosphate of lime is changed into crystallized pyrophosphate, which, when still more heated, will get fluid like glass. Probably it loses in this state part of the phosphoric acid, and changes into a tribasic phosphate. The stirring is kept up until the mass is fluid like glass, and quite transparent, and shows no more bubbles. It is then put into another pot and subjected to white heat for two hours, for which time the stirring is always kept up. After this let the mass stand for about an hour, and put on a metallic surface or a metallic mortar. Rapid cooling must be avoided. When it has a putty-like, consistency, the mass may be put on plate glass, and can be taken off easily when cold. From such a plate quite a number of stones can be cut, which are almost equal to the genuine gems in every respect.

Another formula for making sapphire is as follows: Bring a mixture of 4 oz. of oxide of aluminum and 4 oz. of red lead (Pb_3O_4) to red heat, and when smelted add 10 grains of bichromate of potassium ($K_2Cr_2O_7$) and 17 grains of oxide of cobaltum (CoO). Stir up well and let cool. Stones cut from this material have the same hardness as the genuine sapphire and are almost of the same brilliancy.

RUBY.

This gem can be made artificially by heating 4 oz. of oxide of aluminum and 4 oz. of red lead to the smelting point and adding then from 7 to 16 grains of bichromate of potassium.

EMERALD.

Emerald, as found in nature, is a combination of the rare element beryllium or glycium with silicon, with its green color due to the chrome contained in it. As the element is very rare, but its hardnes even less than that of ruby, the aluminum oxide can be substituted. 4 oz. of oxide of aluminum, 4 oz. of red lead, to which from 8 to 12 grains of uranate of sodium ($Na_2U_2O_7$) are added, and which mixture is treated in the same way as described, will make the best imitation of the emerald. Uranate of sodium is used very extensively for the manufacture of stained glass, porcelain, etc.

Also the manufacture of imitations of crystal quartz, amethyst, topaz, etc., has been brought to great perfection by Donault Wieland, at Paris. The basis of these imitations is pulverized quartz or crystal quartz. The so-called Parisian diamonds, or "Alaska" diamonds, are made by heating 65 per cent. pulverized crystal quartz, 20 per cent. red lead, 8 per cent. pure carbonate of potash, 5 per cent. boric acid, 2 per cent. white arsenic, as described. The brilliancy of the stone mostly depends on the purity of the red lead and the carbonate of soda. Improvements in the chemical processes, as well as in the technical preparations, heating, and ventilation, have done a good deal to lower the price of the artificial gems and to make them of a hardness which makes them fit to be cut in the most effective manner.—*Jewelers' Journal.*

PAPER and leather may be rendered very pliable by soaking in a solution of 1 part acetate of sodium or potassium in 4 to 10 parts of water, and drying—*Polyt. Notizbl, from Am. J. Ph.*

HARLOW VICARAGE, ESSEX.—GARDEN FRONT.

THE PANDISCOPE, OR LANTERN SKETCHER, AND THE "PRESTO" PHOTOGRAPHIC SLIDE CARRIER.

HAVING witnessed what may be well deemed a rather unusual phenomenon in connection with the lantern, the tracing of the outline of a well known photograph in luminous lines on a previously dark screen, we purpose describing the same. Unless we had witnessed it, we could not, from a mere verbal or written description, have realized the sensational effect capable of being produced by this "handwriting on the wall."

The special piece of apparatus by which this rather startling result is achieved is made by Mr. W. C. Hughes of Brewster House, Mortimer Road, N. It consists of a wooden frame capable of fitting easily into the slide receptacle of any ordinary lantern of the average size. But instead of the usual transparency, a square of plain blackened glass is inserted into the slide, so that when the lens is uncapped and the light full on, nothing whatever is seen on the screen. But presently bright, luminous lines are observed, traced by some unseen limner and by an agency which cannot be dis-

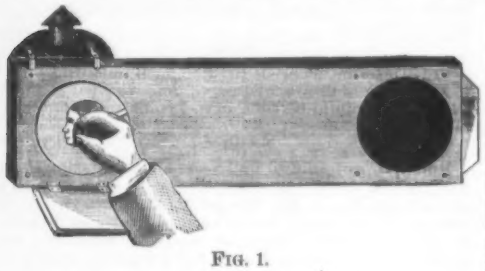


FIG. 1.

covered; and speedily the outlines of a picture, landscape, or portrait cover the whole space on the screen. The figure, picture, portrait, or writing unfolds itself before the spectators with the same exactness and precision as though it were performed by a pencil upon paper.

By aid of the following diagrams, the mechanical agency by which this surprising effect is produced will be plainly understood. Fig. 1 represents the frame or slide, the right-hand end of which is inserted in the lantern, the black disk being central with the condenser. At the opposite end is affixed a lamp, the light from which serves to illuminate any small photograph or print which is pressed against a plate of glass. This lamp being carefully covered, no light from it is seen by the spectators in front. A small handle, to which is attached a tracing point, is grasped by the right hand of the exhibitor, and is moved so as to guide the point of the tracer over the drawing, with this result—that every touch made by the hand is reproduced at the other end by a needle point which moves over the

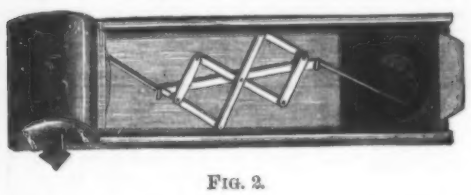
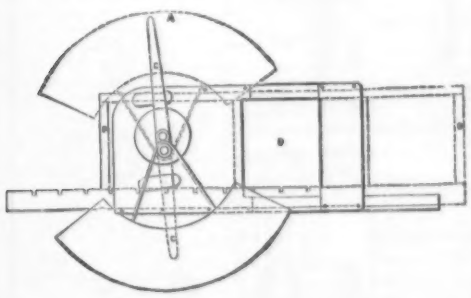


FIG. 2.

blackened glass. When the tracer is lifted from the drawing, the needle point is also removed from the blackened glass.

The means by which this is effected is shown in Fig. 2, which represents the opposite side of the slide, and shows the back of the lamp and the combination levers, by which each touch of the tracer is repeated at the opposite end. This reproduction is upside down, as, of course, it ought to be in order to its non-inversion on the screen.

This piece of mechanism, which is designated the *Pandiscope*, or *Lantern Sketcher*, was first conceived and originated for the lantern by the Rev. L. Blandford Hill, and finally developed and placed in its present form by Mr. Hughes. There seems no limit to the uses to which this instrument may be applied, for any photograph, sketch, or engraving can be readily attached to the easel in front of the lamp, and a drawing made with perfect ease by the tracer. It will certainly be much adopted as a useful *addendum* to the lantern when it becomes more generally known.



Of the various ways by which the glasses can be blackened, probably the quickest and best is to ignite a small piece of camphor and hold the glass plate over it.

While on the subject of lantern *addenda*, we may allude to the method adopted by Mr. Hughes for effecting the change from one slide to another without any movement being observed on the screen. This, like the *Pandiscope*, consists of a slide frame, D, capable of being inserted into any lantern of the ordinary size. It receives a double runner or holder, B, capable of receiving two transparencies. The aperture, D, is in the axis of the optical system. It should be premised that the shutter, A, shown at the bottom of the diagram, is formed of a thin sheet of ebonite and is several inches in front of the slide, being capable of such adjustment as to cause it to rotate in front of the lens or objective of the lantern.

By taking hold of a handle and rotating it, the shutter acts as a cap to the lens, and cuts off the light from the screen, which is no sooner effected than certain teeth which project from a circular plate (not shown in the diagram) act in notches in a tailpiece of the running plate-holder, and cause it to move horizontally the full distance requisite for it to travel in order to bring the second transparency in the axis of the condenser, when, by continuing the rotating motion of the shutter, the lens is uncapped and the new picture is seen on the screen, the change having been effected during the moment of darkness caused by the passage of the shutter over the lens. This shutter at each change assumes the positions shown at A and A respectively, above and below the slide.

The change from one picture to another takes place with any degree of rapidity desired, and with the most perfect smoothness of action. During the time the picture is shown on the screen, the running slide holder is locked by a catch which falls into one of the notches and it can only be released by rotating the shutter or screen.

Mr. Hughes designates this his "*Presto*" *Instantaneous Photographic Slide Carrier*, and in action it quite bears out all that is implied in the name selected.—*British Journal of Photography.*

THE ASTRONOMER ROYAL OF IRELAND.

SIR ROBERT STAWELL BALL, LL.D., F.R.S., Andrews Professor of Astronomy in the University of Dublin, and Astronomer Royal of Ireland, has received the honor of knighthood. This distinguished man of science was born in 1840, at Dublin, his father being an eminent naturalist, who became Director of the Natural History Museum, and Secretary to the Queen's University in Ireland. The son was educated at Trinity College, Dublin, from 1857 to 1865, under Dr. Kells Ingram, and won the mathematical studentship. He became tutor to the sons of the late Lord Rosse, at Parsonstown, and engaged in the mechanical and as-

SIR ROBERT S. BALL, F.R.S., ASTRONOMER ROYAL OF IRELAND.

tronomical studies to which that nobleman was devoted, availing himself of the great telescope and other apparatus in Lord Rosse's celebrated observatory. In 1867, Mr. Ball was appointed Professor of Applied Mathematics in the Dublin Royal College of Science. He had already gained a reputation, and proceeded to increase it by his lectures, published treatises and memoirs, and contributions to learned societies, upon mechanics and dynamics, "The Theory of Screws," more completely expounded in a volume published in 1876, as well as upon astronomical subjects and mathematical researches. In recognition of the merit of his experimental inquiries concerning vortex rings, and other subjects, he was elected a Fellow of the Royal Society of London in 1873, and the degree of LL.D. was conferred upon him by the Dublin University. In the next year he was appointed by that University to the Professorship of Astronomy—which had been held by Dr. Brunnow, and previously by Sir William Rowan Hamilton and Bishop Brinkley—with the office of Astronomer Royal. Sir Robert Ball has written not only scientific treatises of high value, some of which are now being translated into German, and which have attracted much notice on the Continent, but has also produced elementary text-books of a popular character: the "Elements of Astronomy," in Messrs. Longmans' series, two of the London class book series, and a recent work, called "The Story of the Heavens," which has been most favorably received. He wrote the articles on "Gravitation" and "Measurement" for the new edition of the "Encyclopedia Britannica," and has contributed to special discussions in the scientific journals. He lectured, on the "Sun's Distance," at the Southport meeting of the British Association in 1883, and in 1884 lectured again at Montreal, before the same association, and before the American Association at Philadelphia; he has also lectured at the Royal Institution in London, and at the Midland Institute of Birmingham. He is scientific adviser to the Commissioners of Irish Lighthouses, and editor of the Admiralty "Manual of Scientific Inquiry;" a vice-president of the Royal Irish Academy, and one of the Council of the Royal Zoological Society of Ireland, taking an active part in these institutions of his native city.—*Illustrated London News.*

THE MICROMETER THREADS AND WIRES OF ASTRONOMICAL TELESCOPES.

ONE of our readers has recently asked us for some information on a subject that is of interest both to

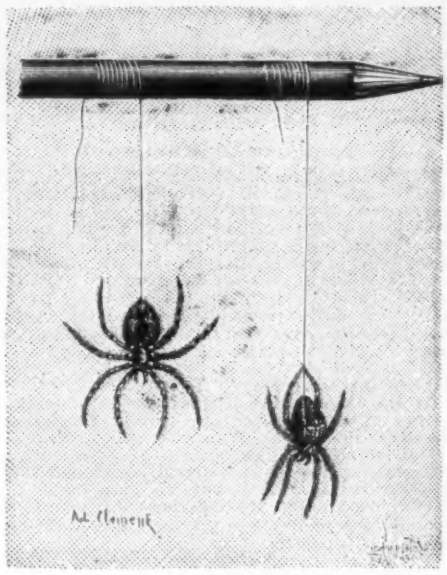


FIG. 1.—EPEIRA DIADEMA.

amateur astronomers and the inquisitive. "What spider is it," asks our correspondent, "that furnishes astronomers with the threads found in the reticules of telescopes? How is it possible to stretch these fibers, which are so slender and delicate that they can scarcely be seen? What other filaments can be substituted for those of the spider, and how are they made?"

As these questions seemed to be worthy of study, we visited the Paris Observatory in order to solve them. Those learned astronomers, the Henry brothers, initiated us into their processes, and had the kindness to send us for illustration one of the spiders from which they are accustomed to obtain the finest threads used in their reticules. Fibers from the cocoons of various

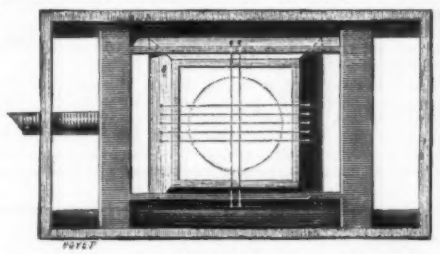


FIG. 2.—SPIDER'S THREADS STRETCHED IN A RETICULE.

spiders are also used, but these are a little larger in diameter than the former. Mr. Traissinet, secretary of the observatory, procured for us some specimens of micrometer wires. We shall tell our readers all that we have learned.

The spider mentioned above is the *Epeira diadema*. The specimen that we show in two positions in Fig. 1 is a male; the female is twice as large. This spider is kept in a small cardboard box containing apertures, and a fly is occasionally given to it as food. It is easily tamed, and, after a few days of captivity, will come of its own accord to seek food at the tip of one's finger. Pellisson's spider, then, may not be a myth. When it is desired to stretch a spider's thread over the reticule of a telescope micrometer, care must be taken to first trace the grooves in which it is to lie with a dividing machine. Then a pencil is placed in front of the spider, and the latter is forced to ascend this improvised perch. The spider soon suspends itself from its thread, which is kept taut through the weight of its body. The thread is now placed in the position that it is to occupy in the reticule, and is affixed above and below to the copper by means of a drop of melted resin. The thread is then cut at the proper places, and the

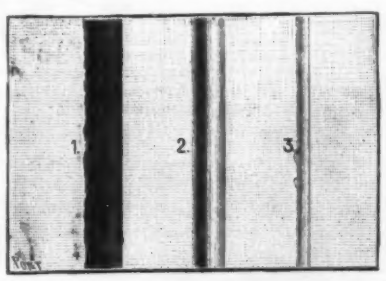


FIG. 3.—PLATINUM WIRE (1), GERMAN SILVER WIRE (2), AND SPIDER'S THREAD (3), MAGNIFIED × 250.

same operation is repeated for the succeeding one. Next, the reticule is turned sideways and the other threads are fixed at right angles with the first, as shown in Fig. 2. Five threads are usually stretched in a reticule, but the number may be larger.

Sometimes Wallaston platinum wire is substituted for spider's thread. These are made as follows: A very fine platinum wire is coated with silver by dipping it into that metal in a molten state. This done,

the wire is drawn as fine as possible, and then submitted to the action of nitric acid, which dissolves the coating of silver, and leaves the insoluble platinum wire intact. In this way platinum wires $\frac{1}{5}$ mm. in diameter, or less, are obtained. Mr. Mouchel, a skillful metallurgist, has succeeded in drawing German silver wires directly, by passing them through diamond or ruby draw plates. In this way he makes wires $\frac{1}{5}$ mm. in diameter.

Having on hand a few specimens of micrometer wires, the idea occurred to us to examine them under the microscope with an amplification of 250 diameters. The Wallaston platinum wire obtained by squeezing in a silver sheath is quite irregular on the surface; it is not polished, but has the aspect of a ragose, black bar. The German silver wire, on the contrary, is brilliant and polished, like a bar of silver. As for the spider's thread, that is much slenderer than its rivals, and the one that we examined did not reach a diameter of $\frac{1}{15}$ mm. As seen under the microscope, it was of wonderful delicacy, and perfectly transparent. Here again nature has the ascendency over human art.—*La Nature.*

AMOUNT OF HORSE POWER USED IN PROPELLING STREET CARS.*

By AUGUSTINE W. WRIGHT.

AT the present time great interest is manifested by street railway companies regarding the question of the substitution of some motive power to propel their cars other than horse-flesh. The various systems, electrical, cable, compressed air, Honigman, steam dummies, etc., etc., are prominently before the public, and each for itself claims, if not perfection, certainly that it is better than any other system.

It appears to me that great ignorance exists upon the part of inventors and street railway companies themselves as to the amount of power required to start a street car and to maintain it in motion under average conditions. The following is an attempt toward a solution of this problem. We will begin with horse power:

Watt's experiments, made with large horses of the London brewers, gave 33,000 pounds raised one foot high in one minute as the power exerted by an average horse, and this, as you all know, is the allowance in figuring engine power. This is on the assumption that a horse can exert a force of 150 pounds over 20 miles per diem at the rate of 220 feet per minute, or 2½ miles per hour during 8 hours. But the horse's power is very variable at different speeds. Tredgold's experiments gave 125 pounds; Smeaton, 100 pounds; Hatchette, 128 pounds; all 20 miles per diem at 2½ miles per hour. Gayffier fixed the power of a strong draught horse at 143 pounds, 22 miles per diem at 2¾ miles per hour, and an ordinary horse 121 pounds for 25 miles per diem at 2½ miles per hour.

As the speed of a horse increases his power of draught diminishes very rapidly, until at last he can only move his own weight.

The following table shows the results obtained by different authors; those of Tredgold being for six hours' daily labor, and those of Wood for ten hours:

Velocity, Miles per Hour.	Tests of Draught according to— Leslie.	Tredgold.	Wood.
2	100	166	125
3	81	125	83
4	64	83	62
5	49	42	50
6	36	..	42
7	25	..	36
8	16	..	31
9	9	..	28
10	4	..	25

From the above table it appears that, according to Wood, at 4 miles per hour a horse can draw only half his load at 2 miles; at 8 miles, only a quarter, etc.

Sir John Macniel estimates his power at 60 pounds, moved 8 miles per diem at same velocity (Gillespie). Wood's Practical Treatise on Railroads contains an interesting chapter on horse power. He made many experiments. He quotes an interesting memorial to the House of Commons, May 3, 1830, from the proprietors of various (33) stage coaches running out of Liverpool, employing 709 horses. These horses traveled an average distance of 13 miles daily, at a speed not exceeding 10 miles per hour, and the stock had to be renewed every *three years.*

Tredgold assigned 37 pounds as the power that a horse should exert over a distance of 10 miles in a day at a velocity of ten miles per hour, or one hour's work. This was founded upon his experiments on stage coach horses. They endured this service only three years.

The speed of North Chicago City Railway cars is 6 miles per hour, including stoppages, and the average time of service is reckoned at five years for each horse, traveling upon selected cobble stone pavement. Before the cobblestone was adopted, the average railway service was four years per horse. The chief street railways of the United States estimate the railroad life of their horses at from three to five years.

May 17, 1881, I had the honor of addressing you on "The Best Pavement for Horse Railroad Tracks." Permit me to quote from that paper: "I recently made the following tests of the force required to start car 110 of the North Chicago City Railway Co., and to keep it in motion after it was under way, using a Fairbanks dynamometer. The track has a grade of two-tenths of a foot per hundred. (This grade is up and down, changing, say, each 250 lineal feet, and is compensated, as the observations were taken upon up and down grades.) The track was not free from sand. Between Chicago Avenue and North Avenue, on Clark, Division, and Clybourn Avenues, 88 tests with an average of 14·8 passengers, weighing (estimated at 140 lb.), with car, 6,772 lb. The force required to keep the car in motion at an average speed of five miles per hour, including stops, averaged 109·5 lb., or per ton 32·3 lb. This is on an old, worn-out iron rail. Between Chicago Avenue and Madison Street, on Clark, on new steel rail, 53 tests, with an average of 20·9 passengers, gave 59·8 lb. as the force required to keep the car in motion. This is an average of 15·6 lb. per ton. The car made 17 starts on this track with an average of 18·7 passengers. Average force exerted to start, 426·5 lb. Average per ton, 116·5 lb. On the first mentioned track, 39 tests, with an average of 18·1 passengers, gave an average force of 487 lb.; average per ton, 134·6 lb.

Recapitulated, the force exerted per ton was, in pounds:

On good track, to start, 116·5; to keep in motion, 15·6.
On bad track, to start, 134·6; to keep in motion, 32·3.

These tests indicate the great loss of power entailed by bad track, and also the great loss in starting; and the better the track, the greater the relative loss in starting. On the poor track, 134·6 lb. per ton was exerted to start, and this is 4·1 times the force required to keep the car in motion. On good track, 116·5 pounds was the force required to start, but this is 7·1 times the force required to keep the car in motion.

Upon the North Chicago City Railway, the average weight of car and its load is 7,740 pounds, or in short tons, 3·87. Passengers averaged at 140 pounds. Our track is now all good. The average force, therefore, exerted in propelling one car is $3{\cdot}87 \times 15{\cdot}6 = 60{\cdot}372$ pounds when the car is in motion, and $3{\cdot}87 \times 116{\cdot}5 = 450{\cdot}855$ pounds force to start. The horses average 137·97 minutes' service per diem. One hundred and three tests upon 17 different cars, open and close, on various lines with different drivers, made by me on different days and hours, give the following average for the horses: Time consumed in stopping, during which no power is exerted by the horse, 13·22 minutes. Time from starting until average speed is reached, 7·88 minutes.

Now the horses average as per above 137·97 minutes daily service.

Deducting time they are not exerting force, 13·22 minutes' daily service.

Leaves actual work, 124·75 minutes' daily service.

Of this power is exerted to maintain motion, 116·87 minutes' daily service.

And extra power is exerted during 7·88 minutes' daily service.

The horse power, therefore, exerted in propelling a North Chicago railroad car, with its average load, by a team in its average day's work, is:

$$\frac{450{\cdot}855 \times 311{\cdot}5 \times 7{\cdot}88}{33{,}000} = 33{\cdot}53 \text{ H. P. starting.}$$

$$\frac{60{\cdot}372 \times 623 \times 116{\cdot}87}{33{,}000} = 133{\cdot}22 \text{ H.P. maintaining motion.}$$

Total..... 166·75 H. P.

This is used during 137·97 minutes, average per minute, 1·208 H. P. per team; or for each horse, 604 H. P.

Upon a poor track, my previously quoted experiments show that this power would be about doubled, or 2·4 H. P. would be used per average car. About ½ of the horse power is used in starting the car (20·1 per cent.). Mr. Angus Sinclair experimented upon the Third Avenue Elevated Railroad, New York, and estimated that the average pull on the draw-bar was five times greater than it would have been if the motion of the train could have been continuous. See *National Car-Builder.*

A. M. Wellington found by his experiments that the initial friction in starting trains of loaded cars was 5·47 times that required to keep them in motion at a speed of 10 to 15 miles per hour. See Trans. A. S. C. E., Dec., 1884. Charles E. Emory, Ph.D., found 11·8 pounds per ton of 2,000 pounds to be the resistance on straight and level track in New York. This is less than my average, but his tests were probably made on a center-bearing rail, the usual rail in New York, and this we know offers less resistance to progress, as the head is comparatively clean, while the step-rail head upon which I experimented was *level with the adjoining outside pavement,* and consequently covered more or less with sand and dirt.

D. K. Clarke, in his work on tramways, states that H. P. Holt found the resistance per gross ton on straight, level track varied from 15 to 40 lb.; Henry Hughes, 26 lb.—often much more, occasionally less; M. Tresca, 22·4 lb. per ton. Subsequently M. Tresca removed two flanged wheels on one side of the car, and then found the resistance 15·25 lb. Mr. Clarke assumes 20 lb. per ton, and says at times it is 40 lb. per ton. "An average of 30 lb. per ton may be taken for the calculation of the ordinary tractive force." In his second volume he states: "The average resistance (30 lb. per ton) already in the first volume adopted for calculation, may be readopted, although an occasional maximum of 60 lb. per ton may be reached, and, on the contrary, a minimum of 15 lb. per ton when the rails are wet and clean, straight and new."

Mr. Clarke's remarks refer to grooved rails, which offer greater resistance than the step rail. General Gillmore estimates this resistance at 16½ lb. per short ton with track in average condition for United States. Mr. C. B. Holmes, President and Superintendent Chicago City Railway, stated that his cable railway required for ordinary operations engines of 477 horse-power; of that it took 389 horse-power to move the cable and machinery. Eighty-eight horse-power (18½ per cent.) was used for the propulsion of 240 cars, weighing 6,000 lb. each, and carrying each 5,000 lb. of passengers. The average speed was 9 miles per hour, or 792 ft. per minute. This statement would indicate that only $\frac{88}{240}$ = 0·367 horse-power per car was required, while my experiments would give: as 3·87 (my average load) is to 5·5 (his average load), so is 1·208 horse-power (used by me) to 1·71 horse-power required.

There must have been some mistake in his test, for 0·367 horse-power = 12,111 foot-pounds. As his speed is 792 feet per minute, the tractive force exerted would be only 15·29 pounds for 5·5 tons, a resistance of less than 3 pounds per ton (2·78 pounds), which is impossible upon a step rail.

Our fellow-member, D. J. Miller, M.E., while employed upon the above-mentioned cable railway, made experiments upon the horse-power used. He found that at an average speed of 6·85 miles per hour or 602·8 feet per minute, 1 horse-power was required for each ton of cable and machinery, and 0·2 of a horse-power for each ton of car and its passengers. For my average load of 3·87 tons, this would equal 0·774 horse-power, instead of 1·2 horse-power as estimated by me. Mr. Miller's 0·2 horse-power = 6,600 foot pounds. His average speed being 602·8 feet per minute, his resistance to traction could have been only 10·95 pounds, including starting the cars. This is 3·94 times the resistance found by Mr. Holmes, but nearly 30 per cent. less than my experiments would indicate. Mr. Miller, however, *assumed* the weight of passengers, having no count of their number, and must have overestimated the load and experimented with the track unusually clean. My average of 15·6 pounds per ton, agreeing so nearly with that of M. Tresca, 15·25, as above quoted, confirms my opinion that it cannot be far wrong. While it is true that M. Tresca's experiment quoted was with only one flanged wheel upon each axle, yet that wheel traveled in a groove, and the resistance could not vary much from my two flanged wheels not in a groove. The car wheels in Chicago are 30 inches in diameter. The horses of the North Chicago Railway weigh about 1,100 lb. each. The speed at which they travel upon the road averages 623 ft. per minute or 7·08 miles per hour. Their average horse-power developed being each 0·604 horse power, equals 19,932 foot-pounds. Divided by 623, the distance per minute, gives 31·99 lb. tractive force. Leslie's estimate at 7 miles per hour was 25 lb. Wood's estimate was 36 lb., at the same speed.

Our horses work daily 2 hours 17·97 minutes, but *seven* days in the week, unless prevented by some unforeseen cause.

I have neglected extra resistance caused by curves, because our lines are chiefly tangents, and it is very difficult to measure the force exerted upon curves, for it varies greatly between 400 and 1,000 lb., upon the dynamometer with the same car and load. My tests were so unsatisfactory upon curves that I have thought it best to omit them entirely. Then, too, the horse walks around the curve, and the lessened speed in a measure offsets the increased resistance.

The greatest exertion of force upon a tangent during my dynamometer experiments occurred in starting a loaded car. It was 1,500 lb., average per ton 283·5 lb. Passing through some slush, caused by snow thrown upon the track, it equaled 75·6 lb. per ton.

In estimating for any independent motor to propel a street car upon the North Chicago Railway, I would take the maximum load and resistance. I have known of 120 passengers upon an open car. Averaging them at 140 lb. each equals 16,800 lb.; car, 4,800 lb.; total, 21,600 lb., or 10·8 short tons. Speed in starting, 0 to 623 ft. per minute; average, 311·5.

$$\frac{10{\cdot}8 \text{ tons} \times 311{\cdot}5 \text{ feet} \times 288{\cdot}5 \text{ lb.}}{33{,}000} = 28{\cdot}9 \text{ horse-power}$$

required. A small portion of this power would be constantly employed, but it must be in reserve. With the electric or cable system no such allowance would be required, for the reason that this excess of power is only needed to *start* the car, and my experiments indicate that the car is starting only one-seventeenth of the time, while it requires no power one-tenth of the time. For each 17 cars upon a line, therefore, it would be necessary to furnish power to *start one* car and to maintain sixteen cars in motion, less the power when stationary, as it is not probable, nor is it necessary, that all should start at the same instant.

During my experiments the cars stopped upon an average each 1,178 lineal feet. We stop only at street intersections, or at the center of blocks more than 500 ft. long.

The following returns are taken from the sixteenth annual report of the Massachusetts Board of Railroad Commissioners:

Name of Railroad.	Number of horses owned.	Number of miles run.	Number of passengers carried.	Average no. passengers per round trip.
Highland	909	1,670,347	10,452,441	43
Lynn & Boston	608	1,052,296	6,364,009	50
Metropolitan	3,183	6,046,879	34,574,135	38
Middlesex	601	1,047,411	7,099,892	45
South Boston	857	1,470,261	9,706,299	41
Total	6,158	11,287,196	68,196,776	Average, 43·4

From the above it appears that the stable average daily distance traveled by the above horses equals 10·04 miles, found by dividing total number of miles run by total number of horses, and this by 365 and multiplying by 2: $\frac{11{,}287{,}196 \times 2}{6{,}158 \times 365} = 10{\cdot}04$.

The average number of passengers for these five railroads per round trip being 43·4 per single trip, equals 21·7. Averaging them at 140 pounds, equals 3,038 pounds. Add weight of car, 4,800 pounds, equals 7,838 pounds, or 3·919 short tons, which is in excess of my average load of 3·87 tons.

It is fair to assume that these horses are worked to the best advantage and that this is all that can be expected of a horse upon a tramway.

The stables of the North Chicago Railway are located at or near one end of each line. The horses are in excellent condition. Their mileage could not be increased, even if it was thought desirable, unless they were changed from car to car upon the road, and this would cause delay and inconvenience. They now make two round trips, and could not make more without adding 50 per cent. to the distance they now travel or changing upon the road.—*Journal of the Association of Engineering Societies.*

* Read November 2, 1885, before the Western Society of Engineers.

A CORRESPONDENT gives some interesting particulars to a Norwegian journal of the habits of herring jumping out of the water when frightened. He states that he has observed whole shoals of this fish, in their anxiety to escape when pursued by whales, piled up above the surface of the sea to a height of from three to six feet. On one occasion the fish formed a mass even with the top of the mast of a fishing-boat, viz., about fifteen feet, and had part of the same fallen into the boat, it would doubtless have sunk.

SIBLEY COLLEGE LECTURES.—IV.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

ON STEAM BOILERS.

By J. M. ALLEN.

WHEN we look out upon our great country or upon the civilized world, and see the rapid progress that has been made in science and the arts, we are led to inquire what is the power or influence that has crowded so much into the last fifty years. Great steamships plow the seas against wind and tide, and arrive at their destination at their appointed time. Railroads traverse our country in all directions like the threads of a gigantic net. Steam cars with their loads of passengers and freight are constantly running from ocean to ocean and from the lakes to the gulf. Acres of spindles and looms are turning out fabrics, not only for home markets, but for the markets of the world. The great iron works of the country with their ponderous machinery are converting the raw product of the mines into the material necessary for the construction of machinery and appliances that bring wealth to the nation and comfort and beauty to our homes. Who are the men that are foremost in these gigantic operations? The men who dare to strike out into new and unexplored fields, and bring such magnificent results out of apparent impossibilities? Not to undervalue the labors of men engaged in purely scientific investigations, it is the men who take the results of such investigations, apply them to the arts and bring them into practical use. These men are known as civil and mechanical engineers, and it is to this class that we are largely indebted for the development of our national resources and the great increase of our national and individual wealth.

But the work is not finished yet. Great strides are to be made in the future; we can only hint at what they shall be. But the work of development will go on until the hum of industry shall penetrate our remotest borders. The men of to-day will soon pass away, and all this important work will fall and is falling upon the shoulders of younger men. What opportunities you have in this school of preparation, endowed by liberal hands and under the direction of eminent and most capable instructors, what opportunities and possibilities are before you! Do not fail to fully appreciate all this, and let the world in the future know that the graduates of Sibley College are most thoroughly trained and fully competent to grapple with the great question so intimately associated with our national progress.

There is one thought which is in my mind that I desire to give expression to. I am deeply interested in young men. I am anxious to see them succeed. I have seen woeful and lamentable failures of young men who possessed splendid abilities, and why? It was because they lacked that underlying fundamental quality that is essential to success. I mean good character. Without this, no man, however brilliant his attainments in other respects, can attain the highest success. Truth, in its broadest application, not only in words, but in deeds, honesty, and industry are the stepping stones to confidence, honor, and power. There is a responsibility resting on all of us that is higher than responsibility to man. A dutiful recognition of that Power which is over and above all, and in whose hands are all nature's subtile forces with which you will be called to deal, will give you light in dark hours and round up a life of activity and usefulness. It will prepare you for the contemplation of those great themes in the life beyond, where all will be made plain.

The great motive power of the world to-day is steam. It is steam that drives our steamships against wind and tide through the pathless deep. It is steam that enables the locomotive to draw its long and heavily loaded trains through the valleys and over the highlands, climbing up even the mountain sides, bidding defiance to heavy grades, and passing over their summits into the valleys beyond. When we stop to contemplate this condition of things, we cannot but be profoundly impressed with the influence of this powerful agency in the hands and under the control of an intelligent mind. It is steam that furnishes the motive power of our manufactories and mills. The tall chimneys that lift their heads high in our cities and villages indicate that there are hives of industry near at hand. The noise of ponderous machinery and the hum of spindles apprises us that the raw material is being wrought into various useful products which will untimately be distributed over the land, possibly over the world. What is steam? Webster defines it thus: "The elastic aeriform fluid into which water is converted when heated to the boiling point." How can steam be made available as a motive power? By confining it in vessels of sufficient strength to withstand the pressure, generated by the application of heat, for the work required.

This brings us to the steam boiler, its proper construction and management, with a view to safety and economy. There are boilers of various types, but as our time is limited, I will discuss only one type, and that is the one most commonly used in this country, viz., the horizontal tubular boiler.

The material of which these boilers are constructed is wrought iron and "homogeneous steel." Wrought iron was formerly used entirely for the shells of boilers. The better qualities were made from charcoal blooms. These blooms were prepared from balls of hot iron in a semi-plastic state, which were hammered in order to work out all the scoriæ and impurities which adhered, while the series of blows upon the mass rendered it malleable, dense, and compact. The blooms were then passed through a series of grooved iron rolls, which reduced them to long, slender bars, called puddled bars.

These were then cut up into short pieces and bound together in a pile and brought to a welding heat in a heating furnace. For the better qualities of iron, these were hammered again while hot to further eliminate the impurities, afterward they were rolled into plates and prepared for market. The more the iron is worked, within reasonable limits, the more homogeneous it becomes, and the more ductile. Such iron is usually branded C. H. No. 1, which means charcoal hammered No. 1. The more ductile products are stamped F. B.—fire-box—and F.—flange. A good charcoal hammered iron, honestly made, is well suited for boiler shells, and should show a tensile strength under test of 50,000 lb. per inch section, and a ductility indicated by 20 per cent. reduction of area at point of fracture under test. It is a lamentable fact, however, that very little of the iron stamped C. H. ever saw a bushel of wood charcoal, and in the haste with which some of it is made, the bars of the pile do not uniformly weld, hence we have laminated plates, which, when put into the boiler and subjected to heat, develop blisters and other defects. We had occasion not long since to make tests of some iron from a fractured plate which was stamped C. H. No. I. It showed a tensile strength of 50,000 and 52,000 lb., with less than 8 per cent. ductility. When bent, it broke with a short fracture and hardly any fiber before reaching 90 degrees.

When a boiler is made, it is next to impossible for any inspection to detect the quality of the iron. In the sharp competition for business, a great deal of poor iron gets into boilers. It is cheaper and the boiler can be sold for less money, and with the improved machinery for flanging, drilling, punching, and riveting, the poor quality of the material cannot be detected. But when subjected to the conditions of use, the frequent repairs soon convince the purchaser that his cheap boiler is a very expensive one after all. "Homogeneous steel" is rapidly taking the place of wrought iron for boiler construction. It is only a few years since this material was thought fit for such use. Its early behavior was quite unsatisfactory, and provoked no little discussion, but with the improved methods of manufacture it is becoming recognized as one of if not the best material for boiler shells. Its ductility and homogeneity are greatly in its favor. These qualities adapt it to the strains caused by the varying conditions of heat, and being rolled from an ingot, it is almost absolutely free from laminations, and consequently from blisters when subjected to heat. We have occasion to test specimens of steel of the different makers. The results of tests of 12 specimens from one maker recently made show tensile strength ranging from 58,210 to 64,329 lb., with a reduction of area at point of fracture in the first instance of $58\frac{15}{100}$ per cent. and in the latter of $60\frac{68}{100}$ per cent. In another case, where 6 tests were made all from the same maker, the highest were 57,900 and 55,020 lb., with a reduction of area for the former of $55\frac{4}{10}$ per cent. and for the latter of $58\frac{6}{10}$ per cent. Elongation in 8 inches for the former, $25\frac{7}{10}$ per cent., and for the latter, $26\frac{1}{10}$ per cent. I regard these as remarkably good steels. We have the records of many other tests, but this will be sufficient to show how a good steel should behave under test. I will say here that the company which I represent has nearly 20,000 boilers under its care, among which are several thousand made of steel, and as a whole they are doing excellent service. We have watched them for several years under the conditions of use, which is the best test, and as a result I can confidently recommend *good* steel as an excellent material for boilers. But I will say here that there is a liability to get a cheap steel. Hence we are liable to have the same trouble that was spoken of in regard to iron. The only safe way is to secure pieces or coupons from the plates before the boiler is made, and subject them to test.

There has been considerable discussion in regard to the different methods of riveting boiler plates together, that is, as to which is best—hand riveting or machine riveting. I should say both may be very good and both may be very bad. Hand riveting is so well understood that little need be said about it. In both the size of rivet hole and rivet should be adapted to the thickness of plate. The most perfect joint is that where the strength of the net section of plate (after the holes are punched) is nearly equal to the shearing stress of the rivets. The usual method of laying out rivet holes for double riveted joints is to pitch them, or put them apart from center to center 2 inches or $2\frac{1}{4}$ inches. If a $\frac{3}{4}$ inch rivet is used, requiring a $\frac{13}{16}$ inch hole, it will be found that so much of the plate has been cut away that the strength of the net section remaining will be only about half that of the shearing stress of the rivets. This is wrong; the rivets should have a wider pitch. To this, many boiler makers will object, claiming that with wide pitches they cannot make a tight joint. The trouble probably is that the rivet holes are not laid out so as to come fair, hence a "drift pin" must be used, and the plate becomes buckled and the joint leaks. If the work is well laid out and well done, there will be no trouble. A drift pin should never be used to bring holes fair that ride one over the other. Suppose we wish to rivet a joint of $\frac{3}{8}$ inch plates with $\frac{3}{4}$ inch rivets; what should the pitch be? For a double riveted joint, we would punch or drill the holes $\frac{13}{16}$ of an inch in diameter and pitch them from center to center $3\frac{1}{4}$ inches. We would also pitch the rivet lines $1\frac{5}{8}$ inches apart. This would give a strong joint and a tight joint if the work was well done.

Now about machine riveting; one of the great difficulties is the careless handling of material to be riveted. It is sometimes hung up by a rope or chain running over a pulley, and raised or lowered so as to bring the rivet holes in a line with the axis of the steam piston which drives the rivet. If the center of the hole and the axis of the driving piston do not coincide, the rivet will be imperfectly driven. In the better class of riveting machines, there are two pistons, one within the other. The outer one moves first and holds the plates in place, and the other follows and drives the rivet. It is the careless way in which the work is done that has brought discredit on machine riveting. Much could be said on this subject, but time will not permit. It was formerly the custom, after the boiler was riveted together, to chip off the edges of the lap with a cold chisel preparatory to calking the joint. This work was often carelessly done. The corner of the chisel was allowed to drag, and a channel was cut along the edge of the plate which greatly weakened it. The surface of the iron was sometimes cut through, and we know that when this is done on a bar of iron, it is easily broken by a sharp blow. Attention being called to this subject by a careless workman, we made the following experiment to ascertain, if possible, why it was that a bar of good iron was so easily broken by cutting a channel across its surface.

When we wish to break a bar of iron, we usually cut a channel with a cold chisel around the entire bar at the point where the break is desired. This having been done, we place the bar on an anvil with the channel slightly over its edge. A smart blow on the outlying portion will cause a fracture, which at first sight has all the appearance of crystallization. Now, if we take this same bar and cut a channel on one side, and subject it to the same treatment with the channeled face up, the crystalline appearance will show slightly, in close proximity to the bottom of the channel, but the main body of the bar will be bent and partly broken, displaying a fiber with a long, silky appearance.

Again, if we take this bar with no previous preparation, and subject it to the same treatment, we shall find that, instead of breaking, it will simply bend, showing no fracture whatever. The question arises, Why, with the same blow, do these different specimens of iron show such widely different results? It has been said that the blow on the cold chisel disturbed the fiber of the iron, weakening it and putting it in condition to fracture at the point cut. Being desirous of demonstrating this matter, and for reasons given below, we obtained a bar of iron $1\frac{1}{4}$ inches wide and $\frac{3}{4}$ inch thick. Instead of using a cold chisel we made use of a file, and cut a channel around the entire bar. We then placed the bar on an anvil with the channel slightly over the edge, struck the outlying portion a smart blow, and it flew from the bar like cast iron. The fracture presented a crystalline appearance. This experiment satisfied us that something other than the disturbance of the fiber by the cold chisel was the cause of this sudden disruption and consequent crystalline appearance.

Some have argued that when the *original* skin of the iron was broken or cut, the strength was greatly reduced, and that fracture in bending was well nigh certain.

To settle this theory, we cut again a channel around the bar, and put it upon a planer and planed away the surface for some distance each side of the channel until the channel was entirely "planed out." The bar was reduced in thickness nearly one-third, but the "*original skin*" of the iron was gone. We next subjected this to the same treatment as described above, and it bent beautifully, with no indication of fracture. This demonstrated to our satisfaction that the "*original skin*" of the iron was not, in this kind of strain, what saved iron from fracture. (It should be stated here that iron of good quality has been broken with an apparently crystalline fracture, where no channeling or previous preparation had been made—see Kirkaldy's experiments on wrought iron and steel—but the circumstances were different from those under discussion here.) When we bend a bar of iron slowly, the fibers on the convex or outer surface of the bend are disturbed very greatly comparatively, and this distention or elongation of fiber decreases as approach is made to the other side of the bar, where a crumpling of the surface fiber will take place.

From a careful examination of the bent portion, the different layers of fibers, so to speak, appear to have slipped or slid one over the other to an extent depending upon the degree of strain brought to bear upon each. Sections cut from the bent portion, when examined with a microscope, show, more or less distinctly, that the laminæ and iron threads have become disturbed and loosened in their cinder envelopes, particularly on the outer side of the bend. If the bending is repeated back and forth several times, the loosening up of the fiber is distinctly seen without the aid of a glass.

Having briefly considered the action of iron fiber in the process of bending, we return to the question of fracture. Why does the bar break suddenly and with a crystalline appearance under a smart blow, at the point marked or channeled with a file? When a bar of iron is bent, the outer fibers receive the strain first, breaking its severity as it is transmitted to those underlying. The disturbing force is distributed over the entire portion of the elongated fiber, diminishing each way from the point of greatest strain. Now, it will be seen that by cutting a channel through the outer layer of fiber the strain is confined to the point where the channel is cut. The fiber on either side to the depth of the channel is not acted upon at all, and exerts no influence as a protection to the underlying layers of fiber; hence, when the blow is received, the effect is confined to the channel, the fiber having little or no opportunity to protect itself, and it breaks short off. When a channel was cut in the bar on both sides, and then planed out, the bar was virtually restored to its normal condition, and its behavior was the same as when in its original condition.

Had we space, allusion might be made to inferior qualities of iron, where in piling the center portions are very poor indeed, while the outside bars are of unexceptionably good quality. This kind of iron presents a good surface, but in bending and breaking, its inferior quality is readily discovered. But the experiments which we made were with good bar iron.

Now, the object of these experiments was this: We not unfrequently find boilers fractured along the edge of the outer lap of the sheet, both transverse and longitudinal, and we further find a great many boilers where the chipping tools have been most carelessly used. The immense force confined in a boiler under pressure is little understood by those not familiar with the laws of steam; and when we take into consideration the fact that this immense pressure is striving to force the surrounding iron into a true cylindrical form, we shall gain some idea of the great strain brought to bear along the lap of the joints—the points deviating farthest from a true cylinder—and the importance of having the iron of the best quality and free from all defects by the careless use of chipping tools, or otherwise.

The fractures found at joints, both longitudinal and transverse, are brought about by expansion and contraction, or by fretting of the iron from uneasy seating of the boiler in its setting; and it will be readily seen that any defect in the iron at or near the point of greatest strain is very liable to result in fracture. Boilers are sometimes met with that are at least one-third less capacity than they should be for the work required. The engine requires more steam than they can easily and steadily carry, hence at every revolution the draught is so great that the hand of the pressure gauge will vibrate through an arc measuring a variation of from ten to fifteen pounds. The boiler feels the accumulating pressure resulting from fires fiercely urged, and expands to its utmost to accommodate it, until the opening ports conduct the steam to the cylinder and afford it momentary relief. With this slow but continuous process of bending back and forth, is it any mystery that boilers finally "give out"? And if, instead of good, sound iron, there are defects at the points of greatest strain, need we look for mysterious agencies when boilers rupture, burst, or explode?

The bracing of the heads of boilers above the tubes in tubular boilers should receive attention. It is true that the flange of the head has good holding power, but the flat portions, if unstayed, are liable, under high pressures, to vibrate and develop weakness or fracture at the flange.

The area of the flat surface should be estimated, also the pressure upon it, and a sufficient number of braces used to provide for that pressure. If the braces are of iron of known strength, say 50,000 lb., a factor of safety of 5 would give 10,000 lb. on each brace of inch section, and the number of braces should be sufficient to provide for the load on the flat surface.

The tubes in a tubular boiler should never be set "staggered." That was the former practice, but it impedes circulation, and provides a place for sediment to settle on the tubes. They should always be set in horizontal and vertical rows, and should never be nearer than 3 inches to the shell of the boiler, and further, they should never be carried down near the bottom of the boiler; but, on the contrary, there should be a good water space or room on the bottom of the boiler. The fire from the furnace first strikes the bottom of the boiler, hence there should be a good body of water there. The practice of crowding a boiler full of tubes is all wrong.

An easy experiment can be made to show that the tubes down near the bottom of a boiler are of little or no use. It is this: Take a clean pine stick, and place it in front of the row of tubes near the center of the boiler at the front end. Leave it there a day, and then examine it. You will find that the top of the stick will be nearly or quite burned off; as you examine further down, you will see that the scorching and charring grows less and less, until, at the bottom of the tubes, it is hardly discolored. This shows that very little of the escaping gases go through tubes near the bottom of the boiler. There should always be sufficient tube area to easily carry off the escaping gases, but it will be found that the levity of the gases naturally leads them to seek exit through the upper tubes, hence all superfluous tubes near the bottom of the boiler are worse than useless.

The deposits of sediment and scale in boilers are often very troublesome. In some sections of the country, the geological formation is such that the waters carry more or less lime and magnesia in the form of carbonates or sulphates. These are sometimes mixed with iron and other ingredients that make a hard and troublesome scale. The only way we have found to render aid in such cases is to carefully analyze the water, and then advise some solvent that will aid in detaching the scale; but in these cases, the boilers must be frequently cleaned, and all the sediment and such scale as can be detached, removed. There is usually some counteracting material that will soften the scale and help to keep the boilers clean, but some of the worst cases have occurred where the water was naturally good. There have been cases where there were several mills on the same stream. Those higher up would discharge their refuse or dyes into the stream, causing great trouble to all their neighbors below. We have known of some cases where chemical works or hardware manufactories have discharged acids into the stream to the great damage of the boilers in the mills further down. These are fruitful causes of boiler deterioration, and if not carefully watched will ultimately lead to disaster.

This brings us to the great question of boiler explosions, but our time will allow us to do little more than allude to the subject. Boiler explosions were formerly attributed to mysterious agencies, and there are some who still cling to that theory, even in the face of satisfactory evidence of weakness or carelessness, or both. After twenty years' study of this subject among thousands of steam boilers, I am satisfied that there is little or no ground for mystery here. The principal causes of boiler explosions are *poor material, fault in type, poor workmanship*, and *careless management*. Material and workmanship have already been alluded to. There are new types of boilers devised every year, but the majority of them have but a short existence.

The tendency to employ cheap engineers is no doubt a fruitful cause of disaster, and under careless management the best boiler may be ruined in a week or less. The desire for excessive pressures, especially on boilers that have been some years in use, and that are not of sufficient capacity for the work required, is another fruitful source of disaster. Steam users in many cases forget that with the enlargement of their works for increased production, they should add correspondingly to their boiler power. They often try to provide for this increase of product by ordering their engineer to increase the pressure on the boilers. This is all wrong, and it invites disaster.

Much could be said on this subject, but we must pass it by for want of time. (At this point the lecturer exhibited some specimens of iron and steel which had been treated with acids, showing the fiber and the flow of metal under pressure. Some very interesting results from experiments on steel plate were shown, also specimens from stub twist and double twist gun barrels. The latter displayed the interlacing of fiber, and the proof prints were very beautiful.)

Before closing, I desire to say a word about experts and expert testimony. As mechanical engineers, your indorsement or approval of this or that machine or scheme will be often sought. Let me advise you to indorse or approve nothing that you do not thoroughly understand, and, further, never sell your opinion for money. A large fee is very tempting bait, but if the scheme back of it is not all right, let it alone. It is an easy matter to forfeit public confidence. If a man is known to be in the market for the highest bidder, his opinions will have little weight with intelligent men. You have a good example before you of an expert whose opinions are widely sought because they are valuable and honestly given. I refer to the Director of this College, Dr. Thurston. Set your mark high, and work up to it, step by step, through honest, patient, and painstaking work.

THE PERMISSIBLE STRAIN UPON BRICKWORK.*

By Dr. BÖHME.

THE experiments given in detail in this paper were made to ascertain the crushing strength of brickwork composed of different kinds of brick with various mortars. The mortars used were made with either lime or Portland cement, in each case mixed with sand. The bricks were those chiefly used in Berlin. The composition of the mortar was found to have great influence upon the strength. Brickwork set in a mortar composed of 1 part of lime and 2 parts of sand possessed only 44 per cent. of the strength of the bricks alone, while the mortar composed of 1 part Portland cement and 3 parts sand raised the percentage to 63. A great number of tests were made; full particulars of each were given. The results obtained are summarized in the following table, in which the safety limit is taken as one-tenth of the absolute crushing strength.

Description of Brick.	Average crushing strength of brick alone.	Permissible strain upon brickwork with mortar composed of:			
		1 lime, 2 sand. 4·3 p. c.	7 lime, 1 cement, 16 sand. 4·8 p. c.	1 cement, 6 sand. 5·5 p. c.	1 cement, 3 sand. 6·3 p. c.
	Lb. per sq. inch.	Lb. per square inch.			
Ordinary Stocks ...	2,030	129	139	161	185
Selected " ...	3,669	162	176	202	232
Clinkers ...	5,360	237	259	296	341
Porous Bricks	4,617	115	125	144	165
Porous perforated Bricks	1,195	53	57	65	75
Perforated Bricks..	2,759	121	132	152	171

The figures arrived at by the author are in each case higher than those upon which the building regulations of Berlin are based.

TIN.

W. P. BLAKE'S paper on tin, in the volume of the United States Geological Survey entitled "The Mineral Resources of the United States," gives the following information concerning the

PHYSICAL PROPERTIES OF TIN.

Tin is a silvery-white metal with a yellow tint. It crystallizes in modification of the square prism. Its hardness is greater than the hardness of lead, and it is softer than zinc. It is not very ductile, but is very malleable. It may be beaten into leaves or foil only a thousandth part of an inch in thickness. The specific gravity ranges from 7·28 to 9·60, according to the purity. It melts at 442° F., and at a temperature much above its melting point it volatilizes. Bars of tin when rubbed emit a metallic odor.

Cry of tin.—The "cry of tin" is the peculiar crackling sound produced when a rod of tin is bent back and forth. It can be distinctly heard when the rod is bent near the ear, and those accustomed to it judge of the purity of the metal by the sound produced.

Purity of commercial tin.—The tin of commerce generally contains a very small quantity of iron and lead and traces of other metals, but rarely exceeding 1 per cent. of impurity. The tin ores of Cornwall taken from the veins yield metal which is less pure than that extracted from the ore washed out of the beds of streams. The stream tin ore is less contaminated with sulphur and arsenic. The metal from the mine ores is commercially known as "mine tin," and that from the alluvial washings as "stream tin." The purest form of tin in commerce is called "grain tin," and the ordinary quality "block tin." The metal known as "crude tin" is contaminated with various other metals in small quantities, but sufficient to render the tin hard and difficult to fuse. It is refined by liquidation and by steaming, and is then called "refined tin." Impure tin is also known as "raw tin." A very small amount of some of the metals greatly impairs the quality. Copper is not as hurtful as iron or arsenic, bismuth, or antimony. One-half of 1 per cent. of these metals makes the tin harder and less ductile. One per cent. of iron makes it friable and dark in color. The purest tins are from Malacca, Banca, and Billiton. Banca tin, known in England as "old tin," commands the highest price. Other India tins are known as "new tin." Banca tin is sold in blocks of 40 and 120 pounds. Malacca tin is pyramidal in form, and the masses weigh from one-half to 1 pound. English grain tin is sold in blocks 2 feet long, 1 foot broad, and 8 inches thick. Inferior grades of English tin are solid bars under the name of "Japanese tin." "Ball tin" is formed by pouring the metal upon a polished plate of copper and then rolling it into balls, which are beaten with hammers and are then stamped.

Powdered tin is, as the name implies, the metal in a highly divided state, produced by shaking it when poured in a wooden box rubbed with chalk on the inside. It is used in the arts to overlay metals or other substances with a thin layer of tin. It is first painted on in a solution of glue or sizing and when dry is burnished and varnished. It gives a brilliant and durable surface of tin.

Permanence of polished surface of tin.—Burnished tin and tin plates retain their brilliancy for a long time if kept from contact with damp and salt air. Roofs and domes of buildings in the interior of the country far from the sea, covered with tin plate, retain the silvery brightness of the metal for years, and do not require painting. Brande cites the fact that burnished tin on one of the pages of a missal of the ninth century, in Alfred's time, still retained its brilliant white luster, although a thousand years had passed since it was laid upon the vellum.

Tin foil.—The great malleability of tin has already been mentioned. It is not only beaten, but is rolled into foils of various degrees of thinness. The value of the metal as compared with lead has led to the invention by Mr. J. J. Crooke of coating the surface of lead sheets with a layer of tin and rolling the two metals out together. The desired weight and strength of the foils are thus secured without using much tin, the greater thickness and weight consisting of the lead upon which the pure tin is spread. Most of the beautiful foils now manufactured for wrapping tobacco and cigars, for capsules, for wine bottles and for jars, are now made in the way described. Great care should be exercised to prevent the contamination of food by the decomposition of the lead of such foils.

Argentine.—The *Engineer* says that the product known in commerce as "argentine," and which is used for printing upon cloths and paper, is a tin moss or sponge obtained by precipitating tin from the chloride solution by zinc. The tin solution must be acid and diluted until it contains 15·85 gallons of water for 150 grms. of tin salt, or in that ratio. The metallic sponge must be carefully collected, washed, and dried. It is then pulverized with water in a mortar, passed through a fine hair sieve, and is mixed with starch paste for printing. The *Chronique Industrielle* says the gray powder can be economically employed for tinning all metals but lead.

Tinning copper.—Tin is largely used, not only for coating iron and mild steel sheets, but also for tinning the surface of copper. Culinary vessels of copper are usually tinned upon the inside to prevent the solution of a portion of the copper by the acids and salt of food in cooking. In France, where such vessels are much used, the tin coating is frequently renewed. Brande gives the following directions for performing the operation: The interior of the vessel is first cleaned and the surface is rubbed over with sal ammonic; the vessel is then heated, a little pitch [or resin] is rubbed over with the surface to be tinned, and tin is applied until the coating is formed. There is usually an excess of tin, which is liable to melt off and get into the food when the vessels are first used.

Disintegration of tin.—It has long been known that tin in pigs and in plates is subject to a peculiar form of disaggregation, especially when exposed to extreme cold and great changes of temperature. The following item from the columns of the *Mining and Scientific Press*, copied probably from a European source, gives a succinct statement of some of the observed phenomena: "The question of the real causes of the so-called disaggregation of tin remains still an open one. Thin sheets of the metal will sometimes, if exposed to the cold for long periods, be covered with blisters, become brittle, fall to pices and finally to powder. The crystalline texture assumed under the influence of cold has been advanced as the probable cause of this peculiarity, while Professor Rammelsberg suggested a dimorphism of tin based on investigations which revealed a decrease of specific gravity in the disaggregated tin, the common specific gravity being 7·29, and that of this modified tin only 7·14. A case was reported in which good commercial tin with the usual amount of three per cent. of lead was, during its transport from Rotterdam to Moscow in a very cold winter, changed into the gray powder described by prior observers. Discussing this and other occurrences, it was pointed out that the continuous vibrations, such as would result from variations of temperature, probably exerted considerable influence in promoting phenomena as here mentioned. The following remarkable occurrence, however, clearly shows that continuous concussions are not absolutely necessary to produce this phenemenon. In a corner of a window in Freiberg cathedral, that had been built up for a long time, a wooden box was found, which, when opened, not without some shaking, showed the fragments of a tin medal and ring, small pieces of reddish gray color, with the surprisingly low specific gravity of 5·8. In this case, as in the others mentioned, a metal with the usual brightness, specific gravity, and other qualities of tin was reobtained simply by heating the gray pieces to the temperature of boiling water. At present, attention is drawn to this phenomenon by an observation of Mr. W. Markownikoff, of Moscow. Some of the tin cans kept in a cold room in one of the Government buildings at Moscow showed blisters, then holes, and finally fell to powder. Once set in the process could not be stopped by removing the cans to a warm room; the destruction ceased, however, if the attacked spots were cut out. None of the cans in use exhibited this disaggregation. Mr. Markownikoff thinks that more or less rapid cooling predisposes the tin to this decay, which is favored by low temperatures."

Similar phenomena have been observed in a lot of bar tin stored in Boston in the winter of 1882-83. At the meeting of the American Institute of Mining Engineers in Boston, February, 1883, Prof. R. H. Richards exhibited bars of tin covered with blaster-like protuberances with a coarsely crystalline structure, while the tin was changing from its malleable to a powdered condition, becoming friable, brittle, and earthy in appearance. These bars were made from a lot of tin amalgam. After the mercury was distilled off completely, as was supposed, the remaining fused tin was poured into moulds, and when cold the bars appeared to be block tin of good quality. Two months later the bars gave signs of falling to pieces. They changed color and assumed the condition described. An analysis showed the composition of the metal to be as follows:

Crystalline part.—Mercury, 2·62 per cent.; tin, 97·24 per cent.; total, 99·86; specific gravity, 6·175.

Malleable part.—Mercury, 2·38 per cent.; tin, 97·50 per cent.; total, 99·88; specific gravity, 7·387.

The presence of mercury thus seems to have been the cause of the changes in the metal. It is probable that other cases of the decay of tin have been similarly produced.

DETECTION OF ADULTERATION OF OLIVE OIL.*

By A. AUDOYNAUD.

TWO c. c. of oil is placed in a tube 150 mm. long and 15 mm. diameter, graduated in c. c., mixed with 0·1 gramm. of powdered potassium dichromate, agitated for a short time, then mixed with sufficient nitrosulphuric acid to increase the volume to 4 c. c., and again agitated. The liquid becomes brownish red, and after the lapse of two minutes sufficient ether is added to increase the volume to 5 c. c., and the liquids are mixed by agitation. The liquid if left at rest tends to separate into two layers, but in a few minutes there is rapid effervescence, nitrogen oxides are given off, and the oil swims on the surface of the liquid with a peculiar color.

With pure olive oil, the color of the upper layer is green; but with any oil containing not less than 5 per cent. of oil of sesame, earth-nut, cotton-seed, or poppy, the color varies from yellowish green to yellow, or even reddish yellow. The color is more easily observed if 4 to 5 c. c. of water is added.

PROGRESS OF THE TELEGRAPH IN CHINA.

THE telegraph extends in an unbroken line from Saigon in the south of the Indo-Chinese peninsula to Pekin, where five years ago there was no telegraph whatever. The rapidity with which, since 1881, it has spread all over China, and has come into general use, is one of the wonders of modern days.

* Mittheilungen aus der "Prüfungsstation für Baumaterialien." Translated for Abstracts of the Institution of Civil Engineers.

* From *Compt. Rend.*, ci., 732, 733. Reprinted from the *Journal of the Chemical Society.*

A THEORY OF THE CONNECTION BETWEEN THE CRYSTAL FORM AND THE ATOM COMPOSITION OF CHEMICAL COMPOUNDS.*

By WILLIAM BARLOW.

IT is not my intention to discuss the generally received atomic theories, or to offer any new suggestions as to the nature of atoms. I shall merely require the following hypotheses as a basis for the theory I am about to submit to you :

1. That atoms, or detached centers of force, exist, and that they in some cases attract, in some cases repel, one another.
2. That the atoms of a crystallizing body, and by this I mean the atoms of the chemist, are kept in their places by the system of mutual attractions and repulsions which they exercise on one another.
3. That the repulsion or attraction, as the case may be, of any two atoms is some function of their distance, or mean distance, apart, and is irrespective of any linking together of particular individual atoms in molecules, if such ever really obtains.
4. That two atoms which when within a certain mean distance of one another are repelled, are attracted when at some greater distance apart.
5. (And this is the foundation-stone of my theory) that the attractions or repulsions exercised by *different kinds of atoms* are *different functions* of the distance.

These are my hypotheses ; the following proposition is based upon them :

If the different kinds of atoms composing a fluid mass are present in such numerical proportions as to admit of a uniform compact symmetrical arrangement in space of the different kinds of atoms with respect to one another, then the occurrence of alternate condensation and rarefaction of portions of the mass, such as is produced by passing wave-movements (those propagating sound, for instance), will everywhere produce an arrangement of the atoms having some degree of approximation to such a symmetrical arrangement.

The proof I have to offer is the following :

It is evident upon the hypotheses I have stated that

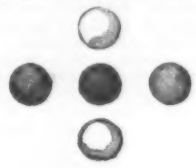


FIG. 1.

when any portion of a fluid mass composed of different kinds of atoms experiences condensation or rarefaction, the atoms will from time to time take up relative positions such that the various attractions and repulsions subsisting at the moment form a system in equilibrium.

And since, by hypothesis, the attractions or repulsions exercised by *different kinds of atoms* are *different* functions of the distance, their arrangement will not generally be similar for different degrees of condensation.

If, however, the attraction or repulsion exercised by a certain atom on another atom is balanced by the attraction or repulsion of a similar atom *placed opposite*

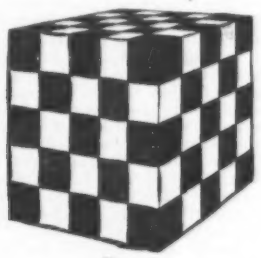


FIG. 2.

at an equal distance, the similar approach or recession of the two similar atoms will cause the forces they respectively exert on the third atom to neutralize one another, whatever the nature of the laws according to which the forces of attraction or repulsion change with change of distance.

To give a simple illustration. Suppose these five balls (Fig. 1) represent five atoms of some system in equilibrium (different kinds of atoms being indicated by different colored balls), and that they have the symmetrical disposition you see ; and suppose that through the passage of some wave of alternate condensation and rarefaction the distances apart of the atoms are similarly changed, that opposite atoms similarly approach, or

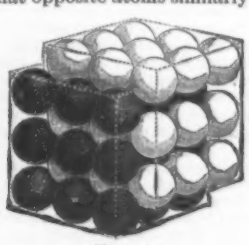


FIG. 3.

similarly recede, from the central atom, then it is clear that, so long as the symmetry prevails, any change in attraction or repulsion produced by the alteration in position of one atom will be compensated by the similar change produced by the simultaneous alteration in position of the opposite atom.

But this will only be the case when the symmetrically placed opposite atoms *are of the same kind*. If two atoms *of a different kind* simultaneously approach a third atom in opposite directions, we shall, by hypothesis, have dissimilar changes in the degree of attraction or repulsion exercised by the two opposite atoms, *and the central atom will move nearer to one or other of them*, and the further the departure from a symmetrical arrangement, the greater the change of relative position of the atoms will be.

It follows that the more symmetrically the various kinds of atoms of a liquid mass are placed with respect to one another, the less change of relative arrangement

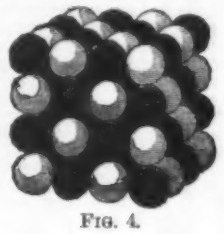


FIG. 4.

they will undergo under the condensation or rarefaction produced by passing waves.

Now, from the fact of the atoms experiencing less change of position the more symmetrically they are disposed, it evidently follows that the most symmetrical and compact distribution of the atoms in space possible will be the system of stable equilibrium toward which they will continually approximate under the rearranging agency of the alternate condensations and rarefactions ; and the more vigorous the rearranging agency is, the nearer the approximation to this symmetrical system of arrangement will be. The proposition which I just now submitted is therefore established.

In cases where more than one symmetrical compact

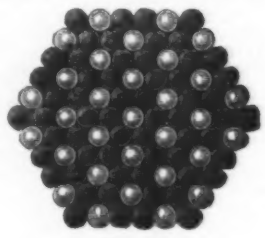


FIG. 5.

system of arrangement of the same atom proportions is possible, it is reasonable to conclude that the system which, under the conditions prevailing, *gives the most stable equilibrium of the forces of attraction and repulsion* will be the symmetrical system toward which the atoms will approximate.

My theory, based on the foregoing, of the origin of the symmetrical disposition of the matter of crystals—a disposition which is revealed both by their forms and their properties—is : *That liquid matter in the act of crystallizing, just before solidification takes place, has the chemical atoms of different kinds which compose it symmetrically arranged in space with respect to one another, and that this symmetrical disposition of the atoms is the direct consequence of the continual condensation and rarefaction of different groups of the atoms of the mass produced by the passage of waves (such, for example, as those which*

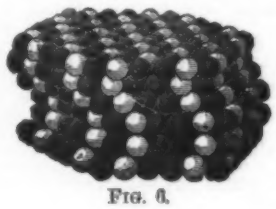


FIG. 6.

propagate sound), and is that disposition which gives the greatest stability under the conditions prevailing.

In support of this theory I am able to point out several cases in which, if the particular numerical proportions of different atoms occurring in certain bodies are arranged in the most symmetrical and compact manner possible, we are furnished with symmetrical systems in complete harmony with the respective crystal forms of the bodies.

First, I will take the very simple case of compounds composed of two kinds of atoms in equal numbers.

There are but two systems of arrangement of *equal* infinite numbers of two sorts of *small* bodies in space which are completely symmetrical, and in which each sort is evenly distributed through space, the perfect evenness of distribution being evidenced by the property that

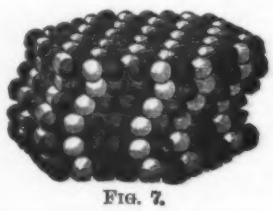


FIG. 7.

when the centers of the bodies nearest to any body of the system are joined, the solid thus outlined has its edges equal.

These two symmetrical systems may be exhibited in the following manner :

Take a number of equal cubes of two different colors, say black and white, and proceed to build them into a continuous mass in such a manner that no cube shall touch any other cube of the same color except at its edges, or in other words, so that a section of the mass parallel to either of the three directions of the faces will present the appearance of a chess-board (Fig. 2) ; then—

1. If, disregarding the distinction of color, we suppose a number of similar small bodies of one sort placed at the centers of all the cubes, and a number of similar small bodies of another sort placed at all the cube angles, we have an example of one of the two systems.
2. If we suppose a number of similar small bodies of one sort placed at the centers of the black cubes, and a number of similar small bodies of another sort placed at the centers of the white cubes, we have an example of the other system.

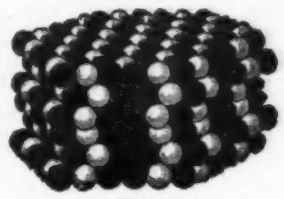


FIG. 8.

Here are two stacks of balls so arranged that the centers of the balls in one stack (Fig. 3) have the disposition of the first of these symmetrical systems, and the centers of the balls in the other stack (Fig. 4) the disposition of the second. Both systems are symmetrical with respect to three axes at right angles to one another and are evidently in harmony with a cubic form.

Now we have the important fact that, as a rule, compounds containing an equal number of atoms of two kinds crystallize in cubes. As instances I may mention potassic chloride, potassic bromide, potassic iodide, sodic chloride, sodic bromide, sodic iodide, cæsic chloride, plumbic sulphide, argentic chloride.

Mercuric sulphide, which crystallizes in six-sided

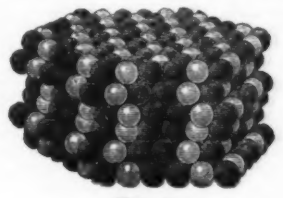


FIG. 9

prisms, is an apparent exception, but if we were guided by the gaseous volume of mercury in determining its atomic weight, we should have two atoms of mercury to one of sulphur in this compound. Other apparent exceptions are zincic oxide, crystallizing in six-sided prisms, cadmium sulphide, and glucina.

The facts as to compounds of equal numbers of two kinds of atoms are, therefore, seen to be mainly in harmony with the theory I have submitted.

Next as to compounds composed of two kinds of atoms present in the proportions 1 : 2.

Infinite numbers of two sorts of similar small bodies present in the proportions 1 : 2 can evidently be arranged in the same plane with perfect symmetry in the way I have here shown (Fig. 5)—one kind of body being placed at the centers of the black balls, the other at the centers of the white—and series of these

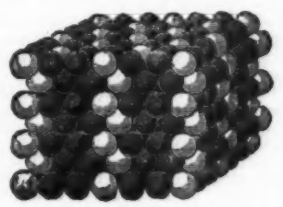


FIG. 10.

plane systems can be ranged parallel to one another in a symmetrical manner in various ways. There are, however, but six different ways in which a number of similar plane systems of this kind can be placed so as to give complete evenness of distribution, as well as complete symmetry, each small body of these six systems being equidistant from the twelve bodies nearest to it.

These six systems are shown by the centers of the balls in these six stacks (Figs. 6, 7, 8, 9, 10, 11). All the

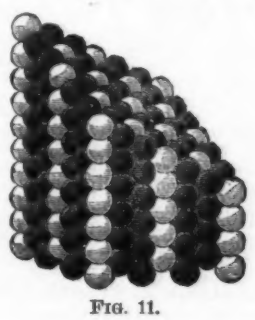


FIG. 11.

six systems have the vertical distances between the plane systems the same.

In four (Figs. 6, 7, 8, 9) the arrangement of the different colors is symmetrical about a vertical axis or direction, balls of one color forming staircase spirals about symmetrically placed lines having this direction. In the other two (Figs. 10 and 11) the arrangement of the different colors is symmetrical with respect to three planes at right angles to one another.

Disregarding the difference of kind of the small

* A paper read before Section B, British Association, Aberdeen meeting, 1885.—*Chemical News.*

bodies symmetrically arranged, we have two kinds of symmetry only; these three systems (Figs. 6, 7, and 10), when considered apart from the differences of color, being identical; and these three (Figs. 8, 9, and 11) also identical.

Now, at first sight we might suppose that the atoms of the compounds under consideration should have the arrangement of one or other of these six systems; but a moment's consideration of our hypothesis, that the attractions or repulsions exercised by the different kinds of atoms are different functions of the distance, shows us that the distance from an atom to the atoms next around it in one of the plane systems (Fig. 5) will not ordinarily be the same as the distance from an atom in one plane system to one of the nearest atoms in the next plane system; for each atom will be exposed to different systems of repulsion and attraction in the two different directions. While, therefore, we shall expect the atoms of the compounds under consideration to be arranged approximately according to one of the six systems depicted, *so far as their situation relatively to a vertical axis is concerned*, we shall not look for the distances between the plane systems to be as in these six systems before you, but shall expect these distances, though equal to one another throughout the same system, to be different in different cases, according to the nature of the two kinds of atoms forming the compound.

In other words, the arrangement of the atoms of a body composed of two sorts of atoms present in the proportion 1 : 2 may be expected to be such that, instead of its being depicted by one of these six stacks of equal spheres, it would be depicted by a similarly formed stack composed of similar and similarly placed spheroids or ellipsoids. In the cases which follow those four of our six typical systems which are symmetrical about a single vertical axis (Figs. 6, 7, 8, 9), the arrangement would be depicted by a stack of similar prolate or oblate spheroids placed with their axes vertical. In cases which follow the remaining two systems (Figs. 10 and 11), whose symmetry is trimetric, the arrangement would be depicted by a stack of similar and similarly placed ellipsoids. The kind of spheroid or ellipsoid to be employed will depend on what kinds of atoms are associated in the compound.

If we make the natural supposition that in all cases the different atoms have the same identical symmetrical disposition with respect to each of the different directions of *corresponding* crystal faces, the six types of symmetrical arrangement I have thus indicated are in harmony with various different symmetrical crystal forms.

Thus the colors in these two stacks (Figs. 6 and 7) have a perfectly hexagonal symmetry about a vertical axis, and, therefore, suggest a regular hexagonal prism terminated possibly by a regular hexagonal pyramid, the inclination of the pyramid faces to the prism faces depending on the kind of spheroid which has to be employed in place of spheres.

The arrangement of the colors in these two (Figs. 8 and 9) suggests a hexagonal prism terminated by trihedral summits, or by hexagonal pyramids with alternate faces similar.

The arrangement of the colors in these stacks (Figs. 10 and 11) suggests trimetric right prisms.

Neither of the six types is in harmony with the cubic system.

Now, most of the compounds of the kind under consideration have their crystal forms in harmony with one or other of our six types.

Thus water, OH_2, crystallizes in six-sided prisms or in rhombohedra.

Quartz, SiO_2, crystallizes in six-sided prisms with pyramids.

Titanic oxide, TiO_2, in square prisms, in right rhombic prisms, and in acute octahedra.

Cuprous sulphide, Cu_2S, in six-sided prisms.

Lead chloride, $PbCl_2$, in six-sided needles.

Lead dioxide, PbO_2, in six-sided prisms.

And mercuric sulphide, which, if—as already remarked—we estimate the atomic weight of mercury according to its gaseous volume, we shall write Hg_2S, crytallizes in six-sided prisms.

About the only compound regarded as consisting of two kinds of atoms in the proportions 1 : 2 which crystallizes in the cubic system is calcic fluoride (fluorspar), and it is interesting to notice that a different atomic weight for calcium which would enable us to write calcic fluoride CaF, and thus add it to the list of compounds containing equal numbers of two kinds of atoms, would also enable us to trace a symmetrical system of arrangement for another compound of calcium, Iceland spar, in accordance with its crystal form; this I hope to show you presently.

In the case of one of the compounds I have just mentioned, quartz or rock crystal, the optical property possessed by this body of rotating the plane of polarization of a polarized ray has been argued to indicate a spiral arrangement of the atoms, right-handed in some specimens, left-handed in others, this conclusion being supported by the well-known experiment of producing similar rotation by means of a combination of thin laminæ of mica arranged in the manner of winding stairs. In connection with this it is interesting to notice the beautiful spirals traced by the black and white balls in some of our six systems (Figs. 6, 7, 8, and 9).

From the rhombohedral symmetry of quartz I suppose that the two systems in which the smaller spirals occur (Figs. 8 and 9) are the types of the pair of systems according to which this substance is built up.

I will now deal with a more complex case, that of compounds composed of three kinds of atoms present in the proportions 1 : 2 : 3.

Since, when infinite numbers of three sorts of small bodies present in these proportions are taken, half of the bodies are of one kind, it is evident that a symmetrical disposition of these, the most numerous kind, will be made if they have the arrangement of one of the sets of bodies in one of these two systems for two kinds of bodies in equal numbers (Figs. 3 and 4). Consequently, we shall have a symmetrical system for the three kinds if we can arrange the two less numerous kinds in a symmetrical manner, so that together they shall fill the places of one set of bodies in one of these two systems.

Now the centers of the balls *of one color* in this stack (Fig. 3) have a similar arrangement to that of the centers of *all the balls* in this one (Fig. 4), and the centers of the balls of *one color* in this one (Fig. 4) have a similar arrangement to that of the centers of all the balls in either of these three stacks (Figs. 6, 7, and 10). And if we remove a corner from this stack (Fig. 4), we see that this system, like the systems of these other stacks (Figs. 6 to 11) may be regarded as made up of plane systems of points arranged triangularly (see Fig. 12). Thus, then, in both these stacks (Figs 3 and 4) balls of two colors present in the proportions 1 : 2 can be arranged with perfect symmetry to fill the positions at present occupied by balls of one color.

When the arrangement of balls of three colors in these various ways is accomplished, we have obtained six distinct typical symmetrical systems of arrangement of three kinds of small bodies present in the proportions from which to derive symmetrical arrangements 1 : 2 : 3, three according to each of the two systems (Figs. 3 and 4).

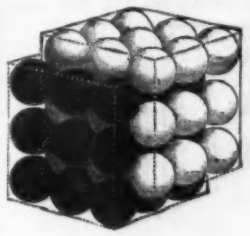


FIG. 3.

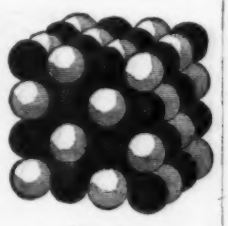


FIG. 4.

Again, three other typical systems for atom combinations of this kind are obtained if we place at the centers of the spaces between the bodies in the three infinite systems of two kinds of small bodies present in the proportions 1 : 2, depicted by these three stacks (Figs. 6, 7, and 10), a third kind of small body, the

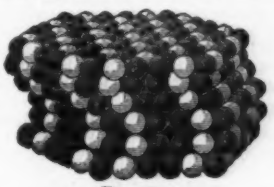


FIG. 6.

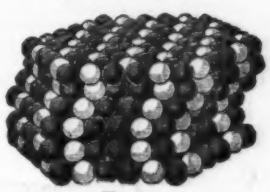


FIG. 7.

systems thus obtained—like the three systems from which they are derived—will evidently two of them be uniaxal, the third trimetric. The latter, derived from this form (Fig. 10), is here depicted (Fig. 13).

As in all the nine systems I have thus indicated, the arrangement of the different colors will evidently not be symmetrical about three axes at right angles to one another, as it is in these two systems (Figs. 3 and 4), we must as in the other cases of symmetry already referred to which are not of the cubic system, employ spheroids

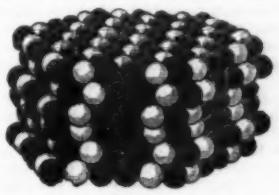


FIG. 8.

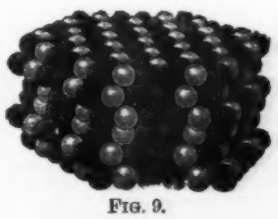


FIG. 9.

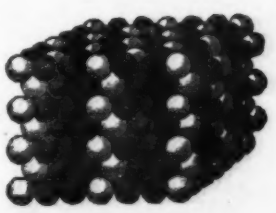


FIG. 10.

or ellipsoids in place of spheres, if we wish to depict the precise symmetrical form proper to any particular case.

In six out of the nine the symmetry is uniaxal, and therefore similar spheroids would be used. In the remaining three cases the symmetry is trimetric, and suitable similar ellipsoids would have to be employed. As before, the form of spheroid or ellipsoid to be used would depend on the kinds of atoms associated in the compound.

I remarked just now that if calcium has but half the atomic weight usually attributed to it, the composition of Iceland spar would be in harmony with its crystal form. I will now proceed to show this.

In this case Iceland spar would be an example of the kind of compound which we have just been considering, for it would contain 1 atom of carbon, 2 atoms of calcium, and 3 of oxygen. (What follows would apply equally well if it contained 1 atom of calcium, 2 atoms of carbon, and 3 of oxygen.)

Now four of the six systems for compounds of this kind which I just now derived from these two cubic systems (Figs. 3 and 4) are symmetrical about a single axis, which has the direction of one of the diagonals of the cube outlined by the stack; and when we employ appropriate symmetrically placed spheriods instead of spheres, we shall therefore, in either of these four systems, have a rhombohedral form in place of the cubic. This is in harmony with the fact that Iceland spar crystallizes in rhombohedra.

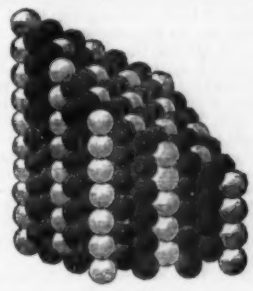


FIG. 11.

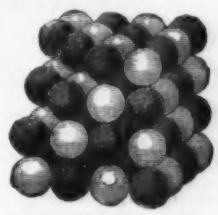


FIG. 12.

It is interesting to notice that in two of the four systems which I have just referred to, those two which are derived from this system (Fig. 3), we have one kind of small body—that which represents the oxygen atoms—ranged in planes having directions exactly corresponding to the directions of cleavage of crystals of Iceland or calc spar.

The dimorphic form of the same compound, known as aragonite, would be referred to one of the three *trimetric* systems of symmetry which I have just traced.

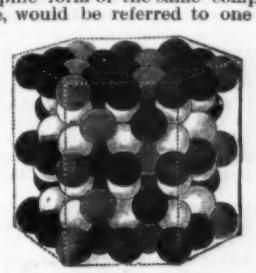


FIG. 13.

It is evident that if we pursue the methods I have thus indicated, a very great variety of symmetrical arrangements of different kinds of small bodies present in various different given proportions may be derived from the few symmetrical systems of arrangement of of points in space of which the models before you are examples. Thus, as another example, we have here a symmetrically arranged plane system of balls of two colors present in the proportions 1 : 3 (Fig. 14). And when these are built up to show the arrangement for compounds of two kinds of atoms present in these proportions, the system produced will be found in harmony with the crystal form of several of such compounds. The very simple symmetrical systems of arrangement of points in space I have selected as typical systems from which to derive symmetrical arrangements for different atom proportions are five in number (Fig. 3 gives one system; Fig. 4 gives a second; Figs 6, 7, or 10, a third; Figs. 8, 9, or 11, a fourth; and Fig. 13 a fifth).

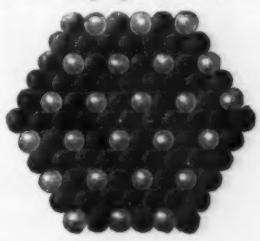


FIG. 14.

The reason for my selection of these particular systems is that they exhibit far greater evenness of distribution of the points than is found in any other symmetrical system of points in space. For four of them are distinguished from all other symmetrical systems by the property that if the nearest points grouped around any point of a system are joined, the solid thus outlined has its edges all equal; and the fifth (Fig. 13) is distinguished by the property that in the case of some of the points, when the nearest points grouped around any one of them are joined, the solid outlined has equal edges; and in the case of the remaining points, when the next nearest points are joined, this is the case.

I would suggest that these five systems probably

furnish all the types from which all the systems according to which the atoms of crystallizing compounds are arranged can be derived, the relative distances between the atoms, and consequently the relative dimensions of the actual systems in different directions, depending however, on the kinds of atoms present, and their relative numerical proportions.

In referring all systems to these few types, there is, however, one observation that I ought to make. The symmetry of a system of different kinds of small bodies will evidently not be impaired by the removal of all the similarly situated bodies of a given kind. For instance, the symmetry, as to the arrangement of color, of this system (Fig. 13) would be equally great if all the least numerous kind of balls were removed, the balls of the other two kinds remaining in the same positions. Now I suppose that where the relative numbers of different atoms present is not such as to allow of their arrangement to fill all the places in a symmetrical system such as is here depicted, a set or sets of symmetrically situated places in the system may be left unoccupied.

Thus the atoms of a compound of two kinds of atoms present in the proportions 2 : 3 might, I suggest, be arranged according to this system (Fig. 13), the places marked by the centers of the least numerous balls being left vacant.

The disposition in space in such cases would not be so even as when all the positions are occupied, but would be improved if the atoms slightly closed in upon the vacant spots in a symmetrical manner.

Several compounds of two kinds of atoms in the proportions 2 : 3 crystallize in six-sided prisms; or in rhombohedral forms (*e. g.*, Al_2O_3 in six-sided prisms; Fe_2O_3,Cr_2O_3 in rhombohedral prisms).

Where many different kinds of atoms are present it is probable that the symmetry of disposition reached is not perfect with respect to all the different varieties of atoms, but that atoms of allied kinds to some extent occupy similar positions almost indiscriminately; perhaps, for the purpose of symmetrical disposition, the atoms fall into three or four classes.

This view is countenanced by some of the facts of isomorphism.

Before closing I may call attention to a few other facts concerning crystals as supporting my theory.

Thus there are close resemblances between the different types. For example, four or five arrangements of points in space may be regarded as made up of similar plane systems of points triangularly arranged. The result of this similarity evidently is that the atoms of a given compound have to make but a slight change of their relative positions in order to pass from one system of possible arrangement to another, and this fact seems to throw light on the readiness with which dimorphic changes occur in some cases.

As an instance of this readiness I may refer to the familiar fact that mere contact with foreign bodies sometimes causes rhombohedral crystals of saltpeter to become turbid, and effects their transformation to crystals of a prismatic form.

Again, the occurrence of dimorphism is in harmony with that variety in the types of symmetrical arrangement of the same atom-combination which I have shown to be possible, and this variety of types further accounts for the variety of forms presented by different compounds whose atom proportions are similar.

The cause of dimorphism we may suppose to be that in some cases slight changes in the relative degrees of attraction and repulsion, exercised by the different atoms of a compound on one another, cause stable equilibrium of their various forces to be found in a different system of symmetry.

The fewness of our types is consistent with the fact of very diverse compounds crystallizing according to the same system.

I suppose that the faces of crystals have the direction of planes which contain a large number of the symmetrically situated points. Thus the faces of cubes indicated by their stacks (Figs. 3 and 4) have the directions of planes containing the centers of all the outlying balls and the faces of octahedra indicated by this one (Fig. 15)—in which the centers are as in these three (Figs. 8,

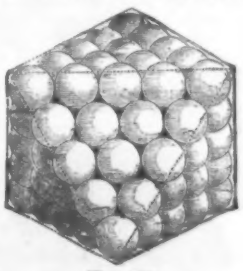


Fig. 15.

9, and 11)—have the directions of planes containing the centers of the outermost balls.

That this relation between the directions of crystal faces and the supposed symmetrical arrangement of the atoms in space subsists is entirely supported by the law of the rationality of the parameters; for if we examine stacks of sufficient magnitude, we find that the series of plane directions actually exhibited by crystals of the same substance are those, and those only, which will fulfill this condition, that they intersect a large number of the symmetrically placed points.

In cases of hemihedral and tetrahedral forms we may suppose that the directions of the faces omitted and the directions of the corresponding faces existing intersect different sets of atoms. For example, in these two hexagonal forms of arrangement of two kinds of atoms (Figs. 8 and 9), pyramid planes drawn to three alternate prism faces do not in any case intersect similar plane systems of atoms to those intersected by pyramid planes drawn to the remaining three prism faces.

The difference of bulk produced in any crystal by a change of temperature we shall naturally attribute to changes in the values of the forces of attraction and repulsion exercised by the different atoms on one another, and in harmony with this we shall refer the fact of crystals not of the cubic system expanding in different degrees in different directions according to their symmetry to the attractions and repulsions exercised by the different kinds of atoms changing differently when a change of temperature takes place.

The phenomenon of the formation of twin crystals is in harmony with my supposition that the atoms in crystals are very evenly distributed in space; for it will be found that the modification of the distribution of the atoms indicated by this phenomenon is not such as perceptibly to impair the evenness of distribution.

To illustrate this. In this arrangement of balls showing an octahedral form (Fig. 15) the balls are arranged according to the third of our five typical arrangements of points in space. When I remove the balls down to the middle layer I get a hexagonal plan, and I have only to shift the upper balls round bodily through 60° and place them in a precisely similar way upon the lower balls, and we get the twin form (Fig. 16).

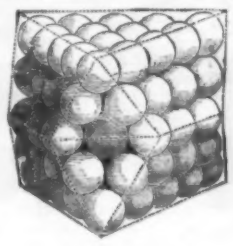


Fig. 16.

My supposition that the arrangement of the atoms of a crystallizing body symmetrically takes place gradually is countenanced by the fact that the longer the process of crystallization is about the larger the crystals produced. For the natural explanation of this, according to my theory, is that the longer any mass, whose atom composition is such as to allow of the formation of crystals, continues in a state of transition from a liquid to a solid condition, the greater the opportunity for the passing waves of condensation and rarefaction to perfect the symmetrical distribution of the different kinds of atoms, *and to make it continuous over larger spaces.*

With reference to the crystallization of the elements, it is clear that the effect of waves of alternate condensation and rarefaction, where one kind of atom only is present, will be to produce the simplest, most compact, kind of arrangement possible—that in which each atom is equidistant from twelve surrounding atoms (Fig. 15).

The greater number of the elements crystallize in octahedra, which harmonizes with this view.

Where they crystallize according to other systems than the regular system, my theory appears to oblige us to conclude that, under the conditions prevalent at the time of crystallization, they contained different kinds of atoms, or atoms having different definite states.

In closing, just a word or two as to isomorphism.

Apart from the distribution of color, three of our five fundamental systems are symmetrical about three axes at right angles to one another (Figs. 3, 4, and 15), and it is evident that a number of atom combinations will be capable of a perfectly symmetrical arrangement with respect to these three axes, according to one or other of these three systems. All compounds whose different atoms can be thus symmetrically arranged with respect to three axes we shall expect to crystallize according to the cubic system, and thus to be isomorphous with one another.

As to other cases of isomorphism, it supports my theory that, as a rule, the isomorphous bodies contain similar proportions of some of the same elements, *e. g.*, calc spar and spathic iron ore.

It is natural to suppose that here the symmetrical systems are similar in the different compounds, and that the atoms common to both have identical dispositions. But it will be asked, How is it that the attractions and repulsions exercised by the atoms which are not common to the different isomorphous compounds do not cause the departures from the root or type form to be very perceptibly different in different compounds? I remark, in reply, that where great symmetry prevails in a system of several kinds of atoms, a considerable variation in the attractions and repulsions exercised by *one* kind on the rest would not necessarily alter the form of the system materially. In other words, the fact of the attractions and repulsions exercised by one set of atoms being different from those exercised by the corresponding set of atoms in a compound isomorphous to it may not produce a perceptible difference of form of the symmetrical systems according to which the atoms are respectively arranged.

In cases where the atom composition of isomorphous bodies is very different, I suggest that the atoms common to both may nevertheless have the same disposition.

Take the case of ammonic sulphate, $(NH_4)_2H_2SO_4$, being isomorphous with potassic sulphate, K_2SO_4.

In this case I suppose that the symmetrical arrangement in the former compound is such that the groups $(NH_4)_2$ occupy places which might, without altering the disposition of the remaining atoms be filled by additional groups H_2SO_4; that, in other words, the relative position of the groups H_2SO_4 is precisely the same as it would be if the entire mass consisted of these groups.*

SIGHT FOR THE BLIND.

In our time the word "progress" is not a vain one, and the day is evidently near when science, realizing the prophecy of the Bible, shall render "sight to the blind, hearing to the deaf, and speech to the dumb." Sight to the blind? It is an almost accomplished fact without appearing so, for the scientists who are occupying themselves with this great problem are industrious workers, who study and experiment in silence, and almost secretly, until they are sure enough of the result looked for to modestly present it to the judgment of academies.

Any one who has for some time past kept track of the communications made to learned societies can now be almost certain that the hour has arrived in which the blind are to see clearly. Some bold surgeons have already attempted to substitute an eye recently extracted from a rabbit for a destroyed human one, and it may be hoped, from the success of these first tentatives, that an "ocular graft" will one day be truly practicable; but what can now be considered as realizable is the repair of an eye that has long been blind—the restoration of sight to an organ that has been accidentally deprived of that function. The ingenious author of this splendid discovery, Dr. Emile Martin, of Marseilles, was led thereto by a very simple reasoning.

Every one knows that in a normal eye the light enters in front through a true window or transparent cornea, and, passing through the various humors, projects upon the retina a reversed image of external objects, just as it does upon the ground glass of a camera. In the dimmed eye of a large number of blind persons, on the contrary, no light penetrates, precisely because the front window no longer allows it to pass—because the cornea is opaque; and if vision is impossible, it is simply because no impression can be made upon the retina.

Fig. 1.—EYE WITH OPAQUE CORNEA.

After many times observing that the eyes of most of the blind that came to him had no other lesion than this want of penetration of light, Dr. Martin conceived the idea that it would perhaps suffice to open an artificial passage for it in such of these organs as had remained sensitive, in order to at once restore sight thereto.

From the conception of this idea to putting it into

Fig. 2.—EYE READY FOR THE RECEPTION OF AN ARTIFICIAL CORNEA.

practice on man, there was a whole series of long and patient experiments to be tried upon animals. With that faith which alone helps to accomplish great things the skillful practitioner did not hesitate to perform such experiments, and he succeeded wonderfully.

What, in fact, was necessary for introducing light again into the closed eye of the blind? Why, a factitious cornea, an artificial window, which should allow the external luminous rays to enter the interior of the eye-

Fig. 3.—ARTIFICIAL CORNEA INTRODUCED THROUGH THE OCULAR MEMBRANES.

ball. Dr. Martin did not imagine anything else. After many experiments, he finally gave the cornea invented by him, and made of a small gold or platinum tube, the form of a nail. This wonderful nail, when inserted in the extinct eye-ball, illuminates it again. As shown by a resumé of a report read to the Academy of Medicine, the introduction of this little apparatus into the ocular membranes is accompanied with no difficulty. By a preparatory operation, Dr. Martin shifts the axis

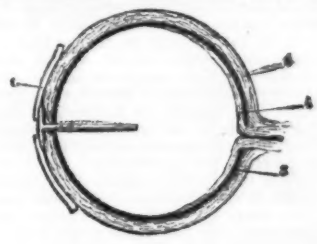


Fig. 4.—SECTION OF AN EYE, SHOWING ARTIFICIAL CORNEA IN PLACE

of the eye in such a way as to bring the atrophied cornea toward the nasal angle.

He fixes the artificial cornea in the center of the white surface of the eye by means of silk thread; then, a few days after the perfect adaptation of the apparatus, the operator opens the central aperture in order to allow day-light to reach the retina. This second phase of the operation is, as may be conceived, the decisive one. If the retina has remained healthy, as oftenest happens, as soon as a luminous ray strikes it the brain perceives the image formed upon it. Thenceforward the blind man sees—the miracle is accomplished.—*L'Illustration.*

STUNNING AND BURN BY AN ELECTRIC LAMP.*

By George Buchanan, Professor of Clinical Surgery, Glasgow University.

Injuries from electric lamps are becoming not infrequent. In most of the cases related, death has been instantaneous. In a case reported on Jan. 22, as occurring at Liverpool, the man was stunned and remained unconscious for a time, and on recovering was found to

* From notes by John Macdonald, M.B.

* The author has offered an explanation of the nature of chemical combination in his "New Theories of Matter and of Force," published by Sampson Low & Co., London.

be quite blind. The case here related is very curious as to its causation and its effects.

William C——, aged forty-four, a workman in Clydebank building yard, was engaged at a crane on Nov. 19, 1885. At the extremity of the wooden arm of the crane was an iron pulley, over which hung an endless chain for raising weights. The man had occasion to pull at the chain, and while so doing an electric lamp, which was suspended above, by some mischance was lowered till it touched the iron pulley. The lamp was one of the arc kind, worked on the brush system. The instant this occurred, the man felt a shock pass through him, became "doubled up," and then lost consciousness; but he did not fall to the ground, being held up by the chain, which his hands firmly and involuntarily grasped. Some three or four minutes elapsed before the electric current was cut off at the machine, when the man dropped down on the ground, stunned. He was taken to the Western Infirmary about an hour afterward, by which time he had recovered consciousness, and could give a distinct account of what had happened. The injuries received were not very severe. There was a vesication on the palm of his hand where it held the chain; also one on the side of his neck which rested against the chain during his pulling it down. On the sole of his right foot in front, where the chief weight of his body rested in the act of pulling, was a spot about two inches square, where the tissues were completely charred by the heat of the current passing into the ground. There were no nails in the boots, and there was no perceptible evidence of heat on them, but the sole of the stocking was charred opposite the charred part of the foot. Sir William Thomson, who questioned the man after his recovery, explains that the moist foot of the stocking must have acted as the medium of conduction between the man's body and the ground, and so determined the seat of the burn.

The symptoms complained of were not very severe; they consisted of a slight amount of general shock, a feeling of heat in the abdomen and chest, and dimness of vision, all of which passed off in twenty-four hours. The wounds were treated in the ordinary way. A large slough separated from the sole of the foot, followed by rapid granulation and cicatrization, and the man was dismissed cured in about six weeks.

Sir Wm. Thomson suggests that if any of the bystanders had taken the man by the clothes and drawn his feet from contact with the ground, or had thrust a bit of dry clothing of any kind under his feet, the contact would have been broken, and the hand relieved from its grasp of the chain. The wonder is that an electric current powerful enough to char the thick integument of the sole of the foot, passing through the man, did not produce any internal mischief.—*Lancet.*

FIRE-PROOF INDIVIDUALS.*

WE shall endeavor to give an explanation of the facts that we have already cited. The hardening of

FIG. 1.—MOUNTEBANK SWALLOWING BURNING TOW.

the epidermis among laborers must in the first place be taken into serious consideration.

In 1774, at the Laune Forge, near Ferte-Bernard, a man walked unharmed over bars of glowing iron, and held lighted coals in his hand and blew them with his mouth. This man's skin was thick, and covered naturally with a fatty and unctuous exudation. The Aïsawa seem to owe their faculty of walking upon red hot iron only to a hardening of their epidermis, the Arabs being in the habit of walking barefooted from infancy.

Blacksmiths are sometimes seen to take up a piece of red hot iron in their hands and carry it a few steps. We have seen a young, callous-handed workman, on a bet, carry a piece of red hot iron to a distance of a hundred yards; but, while doing this, he rapidly and continuously threw the iron from one hand to the other so as to avoid too long a contact.

We have likewise seen a farrier pick up and throw aside a red hot shoe that had fallen on the thigh of a fettered horse. Certain farriers, also, will take a white hot shoe out of the forge fire with their hand and lay it upon the anvil. An old employe of the Omnibus Company performs this feat with the greatest ease.

Cooks will pick up with their fingers a burning coal that has fallen out of their range. A country laborer will extinguish a candle by pinching the wick with his thumb and forefinger, and he will, in the same way, smother a piece of burning paper with which he has just lighted his pipe.

* Continued from page 8436.

These are examples of proof against fire due simply to the hardening of the epidermis through labor. This, however, does not suffice to fully explain the tricks of those individuals who exhibit in public as fire-proof. The experiments of the Italian physician and chemist Sementini have shown, in fact, that there are preparations which, when put upon the skin, render the latter absolutely insensible to contact with fire or incandescent materials.

At the beginning of the present century, a Spaniard exhibited himself at Paris as being endowed with a supernatural incombustibility. His experiments were nearly the same as those of the man Richardson, of whom we have already spoken, and, like these latter, called forth a discussion among French physicians and scientists as to how they were performed.

At nearly the same epoch an Italian named Lionetti performed some tricks of this kind at Naples, and was carefully observed by Sementini, who was then chief professor of chemistry at the university of that city. Lionetti began by rubbing a bar of red hot iron over

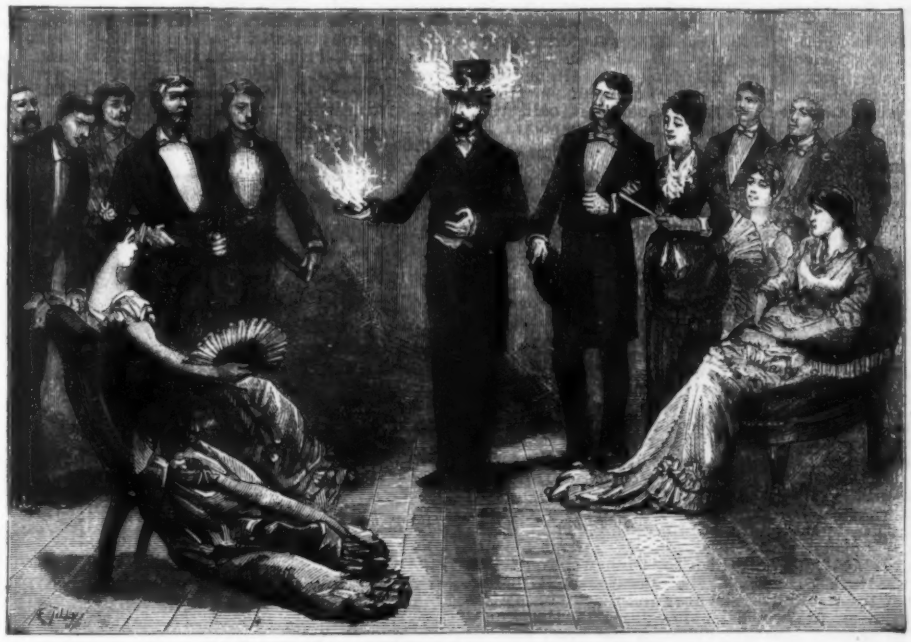


FIG. 2.—KORDIG'S EXPERIMENTS AT THE CONSERVATOIRE.

his hair without burning the latter, and afterward passed the same over his arms and legs. He kicked a piece of white hot iron several times with his toes and heel, placed a piece of red hot iron between his teeth, drank boiling oil, dipped his fingers into molten lead, and let drops of the latter fall on his tongue, and passed a red hot iron rod over his tongue without appearing to suffer from it in the least. He exposed his face to flaming oil, or to the vapor disengaged from sulphuric, nitric, and hydrochloric acid poured upon glowing coal.

Sementini resolved to ascertain the secret of these experiments. He especially remarked that at the moment the performer passed a bar of red hot iron over his head, a large amount of whitish and opaque vapor was disengaged from his hair, that the same was the case when his arms, legs, or feet were in contact with the iron, and that when he poured molten lead upon his tongue, or touched the latter with a hot iron, its surface became covered with a white substance nearly like the saburra deposited by fever. From these observations Sementini concluded that Lionetti made use of preparations that preserved the epidermis for the moment, and he resolved to determine the nature of them. His first experiments had no result. Finally, after submitting himself to repeated friction with sulphurous acid, he was enabled to apply a bar of red hot iron to his skin with impunity. Continuing his experiments, he found that a solution of alum had the same property. One day, having accidentally rubbed soap upon the surface of a hand that had previously been impregnated with alum, he found that the hand was still further proof against fire. He then dared to put a red hot iron upon his tongue. He even discovered that a layer of powdered sugar covered with soap sufficed to render his tongue entirely insensible to heat.

After all these experiments, Sementini succeeded in making himself much better proof against fire than was the charlatan who had suggested this kind of study to him.

Such is, according to this learned chemist, the secret of the man proof against red hot iron and glowing coals. It is certain that those poor mountebanks who perform experiments of this kind in side shows at fairs use either the preparation discovered by Sementini or something else of the same nature.

Fire-Eaters.—The persons above mentioned usually complement their experiments with the more or less real digestion of burning substances. An enthusiastic witness of Richardson's experiments narrates the following in the *Philosophic Transactions:*

"He swallowed molten iron, and pitch, sulphur and wax mixed together, and the whole burning so that the flames issued from his mouth; and this composition made as much noise in his throat as does hot iron when dipped into water." Besides, as we have seen, he put live coals into his mouth, and cooked a bit of meat on them.

At about the same epoch (end of the seventeenth century), the physician Thoisuard asserted that he had seen at Orleans a lady who allowed lighted wax to drop upon her tongue. In our day, the eating of fire has become a simple trick of dexterity that is performed by mountebanks who exhibit in public. All these things, which at first sight seem so extraordinary, are very easily explained. Apropos of Richardson's performances, Dodart remarks that the tongue, which is so sensitive to savors, is, relatively speaking, not very impressionable to heat, especially at its surface. Very delicate persons are observed to swallow food of an extremely high temperature. He remarks that coal gives up its caloric as soon as it is extinguished, and that many persons can place a piece of incandescent coal upon their tongue, provided they moisten the latter with a little saliva. Dodart shows that the coal upon

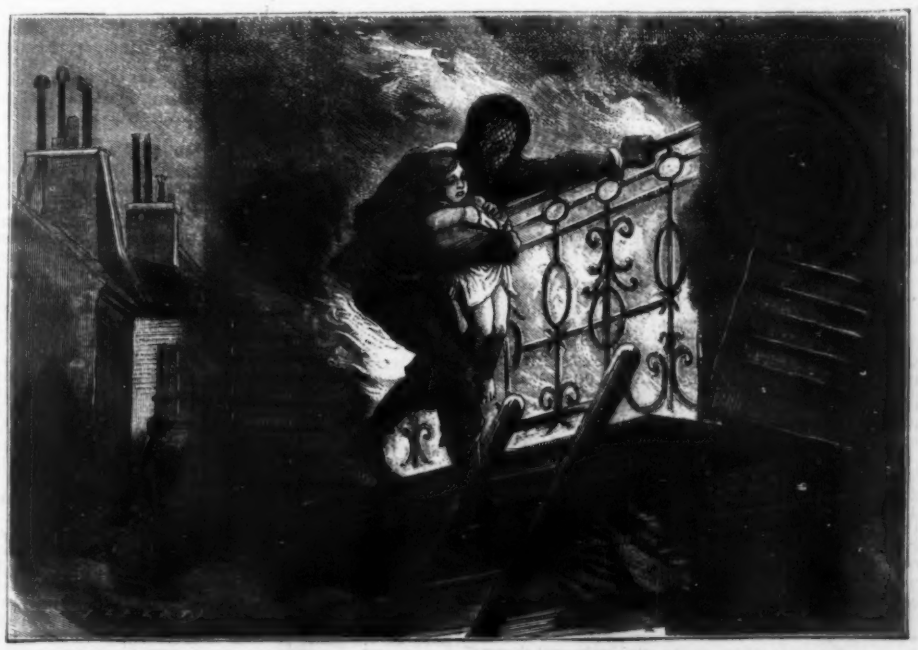


FIG. 3.—SAVING LIFE THROUGH THE USE OF FIRE-PROOF CLOTHING.

which Richardson cooked a bit of meat or an oyster was more than an inch away from his tongue, which latter he took care to cover with a piece of flesh, and that the blowing, which was supposed to quicken the fire, served rather to cool the tongue of the performer than to make the coal burn more briskly. As for the lighted mixture of wax, sulphur, and pitch, Dodart asserts that he has found it possible to hold his finger therein for two seconds without feeling any pain. He observes that the majority of burning materials that are put into the mouth are extinguished as soon as the latter is closed, and that the nature of the gas which is exhaled from our lungs must still further hasten the extinction.

This last remark explains the trick, attributed to a sea captain, of swallowing burning brandy in the presence of some Hottentots, who thereupon prostrated themselves at his feet and proclaimed him the greatest fetichist in the world.

To breathe fire, flames, or smoke is scarcely any more difficult. We see this trick performed every day by montebanks in the side shows of fairs, and also in circuses. The processes employed by those who breathe fire are very simple. Certain eaters of burning tow are satisfied to form a little ball of the material, which they tightly compress and then light and allow to burn almost entirely up. Then, rolling this in new tow, in order to guard the mucous membrane of the mouth against contact with the incandescent ball, they breathe gently, taking care while doing so to inhale only through the nose, and thus project smoke and sparks. Another and more improved method consists in introducing into the mouth a sort of clay or metal pipe-bowl stuffed full of carbonaceous material, and in breathing gently through a mechanism analogous to the one employed when the blow-pipe is used in chemistry.

Volatile Liquids.—There are some liquids that have the property of taking fire and burning without injuring the objects upon which they are poured, or without producing any painful sensation on the skin. As a general thing, such liquids are very volatile, and consist of essential oils, ether, etc. Certain persons will put a little ether in the palm of the hand, light it, and let it burn without experiencing the least sensation of heat. A few years ago the inventor of a new illuminating product (a Mr. Kordig) performed some curious experiments before several learned societies and at a soiree given by Mr. Hervé Mangon at the Conservatoire des Arts et Metiers. These were described by *La Nature* at the time, as follows: "Mr. Kordig poured a quantity of the liquid upon his hat and set it on fire, when a great flame shot up to the ceiling. Then, to the great astonishment of the spectators, he put his hat upon his head and waited till the flame went out. The has was intact (Fig. 2). The operator next poured some of the liquid over the floor and set fire to it without injuring the wood. A few drops of the liquid may be poured into the hollow of the hand and be burned therein without any appreciable sensation of heat being experienced."

How substances can be burned upon objects without injuring the latter, or upon the skin without occasioning a burn, is explained in this wise: These substances are very volatile, and their tension is considerable, and, in reality, when they are burning, it is merely their vapor that is on fire. This vapor then tends to borrow heat from the liquid, whence the latter may remain at a relatively low temperature while its surface is on fire. This is the reasonable explanation of the curious phenomenon of a liquid burning in the hand without injuring the latter.

Fire-proof Clothing.—An endeavor has been made to make fire-proof clothing that should permit of flames being entered with impunity, either for the sake of saving life or for more easily fighting a fire. Among the attempts in this direction may be cited those of Chevalier Aldini, whose clothing consisted of wire gauze and strong cloth saturated with alum. The head was protected by an abestos hood, and the hands were incased in asbestos gloves. In order to show the efficiency of his clothing, the inventor performed a series of curious experiments in 1830. Thus clad in his costume, he took a red-hot iron bar and carried it to a distance of over fifty feet, set some straw on fire with it, and returned and put it into the furnace. Another time he carried a burning beam, and walked upon a grating beneath which fagots were burning. Six men clad in this fire-proof costume walked slowly between a series of fires forming a passage over ten yards in length filled with flames and smoke. One of these experimenters passed through the furnace carrying a wire-cloth covered basket in which there was a child. Courageous men, through fire-proof clothing, have, at fires, been enabled to thus enter the flames and effect remarkable rescues (Fig. 3).

A few years ago, some experiments were performed at Paris with a fire-proof costume of another style, which consisted of plates of sponge juxtaposed and united in such a way as to form a complete envelope. These sponges, once saturated with water, constituted a genuine liquid cuirass, which, interposed between the flames and the body, preserved the latter against burning. From time to time a stream of water was directed against the experimenter in order to keep the sponges wet and the clothing fire-proof.—*La Nature.*

THE STORY OF BIELA'S COMET.

By H. A. Newton.

A LECTURE DELIVERED MARCH 9, 1874, AT THE SHEFFIELD SCIENTIFIC SCHOOL OF YALE COLLEGE.*

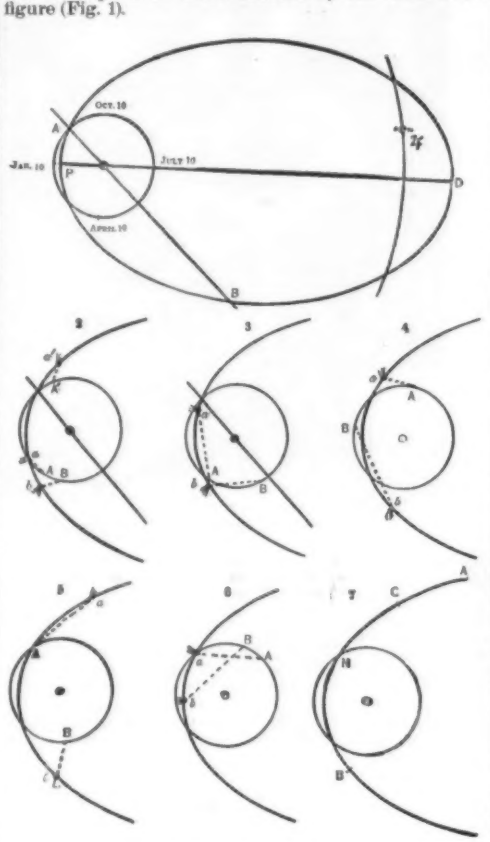
Ladies and Gentlemen: I ask you to listen tonight to the story of Biela's comet. I will weave into the story enough of astronomy to justify its place in this course as a lecture.

The story has none of the interest which human passions give to stories of human life, and yet if it shall not be to you as interesting as a novel, it will be because I shall spoil the story in telling it to you. It is a true story. In other words, I mean to separate sharply what we know from what we guess.

One hundred and two years ago last night (March 8, 1772), a Frenchman named Montaigne, in the provincial city of Limoges, found a comet. He did what little he could with his small telescope to mark its place in the heavens, but it was not much that he could do. The comet was a faint one, not to be seen by the naked eye, and had a short tail, only one-eighth as long as across the disk of the moon. He did not dream that that little foggy speck of light was to be one day one of the most interesting comets in the solar system; in fact, that he himself was to be known to history only for having first seen it. This little comet is the hero of my story—a hero from humble life. Montaigne wrote to Paris of his discovery, and they saw it three or four times before it disappeared.

Thirty-three years later, November, 1805, another Frenchman, named Pons, saw the comet. It passed rapidly from the northern heavens, and in a month went below our horizon. It came this time very close to the earth, and I shall in a moment tell you how it appeared. It was visible to the naked eye, even in strong moonlight. Twenty years later, February, 1826, an Austrian officer, Von Biela, again found the comet. So soon as an orbit could be computed, it was seen that the three comets of 1772, 1805, and 1826 were the same body. This has since been known as Biela's comet. Its exact path around the sun could now be told. Let me show it to you.

Let us look down upon the solar system from a point several hundreds of millions of miles north of it. Looking southward, we should see the sun in the center. The earth, with its moon, would travel around the sun in a path or orbit denoted by the circle in the figure (Fig. 1).



Figs. 1 to 7.

It goes about the sun once a year, being, on the 10th days of January, April, July, and October, at the points so marked on the diagram. The motion is opposite to that of the hands of a watch. Outside, five times as far from the sun as is the earth, will be the huge planet Jupiter, a part of whose path you see. It goes about the sun once in twelve years. The paths of the other planets are not in the figure, as I have nothing to say about them to-night. In the figures which I show you, the earth's orbit is twenty inches in diameter, or one inch to nine million miles. An express railway train traveling all the time for a fortnight would pass over about the thousandth of an inch in this figure. The comet's path is the ellipse. Around this ellipse it traveled three times in twenty years, or once each 6⅔ years. When nearest to the sun, or at perihelion, it went within the earth's orbit, and when most distant it passed beyond Jupiter.

The comet's motion is very unequal. At D it moves very slowly. As it falls toward the sun the sun's attraction makes it move faster and faster, so that it whisks rapidly by P. As it then rises from the sun on the other side of the orbit, the sun not only turns it ever out of the straight path it would move in, but it stops its upward momentum, so that when it reaches D again it has only its old velocity with which to repeat its circuit. At P its velocity is twenty-eight miles, at D four miles, a second. In fact, to pass over the part lying apparently outside of Jupiter's orbit, just half of the whole 6⅔ years is required. I said *apparently* outside, for another fact must be noticed: while Jupiter and the earth may be said to move in the same plane, that of the figure, the comet's orbit lies at an angle. Suppose the ellipse to be a metal ring, and let it turn about the line AB as a hinge, the part ADB rising toward you, and the part APD retreating from you. The parts near D must rise about the half-diameter of the earth's orbit to give the true position of the two planes. Notice that the comet's and the earth's orbits cut each other at the node on the line AB. The importance of this fact will by and by appear. The two orbits seem to cut each other at another point (below P), it is true, but because of the angle of the planes the cutting is only apparent.

Like all other comets, this one was visible only when near the earth and near the sun. Through the outer part of its path it was never seen, even with a telescope. The comet was seen in 1826 for the third time.

Positions in 1772 *and* 1805.—In March, 1772, it was first seen from A in the direction A*a* (Fig. 2). It was last seen four weeks later from B in the direction B*b*. In November, 1805, Pons found it when the earth was at A′ and the comet at *a*′ (Fig. 2). Both the earth and the comet were going to the node, the comet going faster than the earth. The earth passed the node just ahead of the comet. I have told you that the comet was then visible to the naked eye even in moonlight, and well it might be. On the 8th of December, with the scale of the figures before you, it was only $\frac{2}{3}$ of an inch from the earth at the node. On the same scale the moon is $\frac{1}{10}$ of an inch from the earth. The comet passed $\frac{1}{12}$ of an inch outside the earth's orbit, but the earth was already past that point.

Dr. Schröter describes the comet: To the naked eye it was (Dec. 8) a large round cloud of light nearly as large as the moon. In a 13 foot telescope it had the same appearance, though it was much smaller, and it had a bright, star-like nucleus. This nucleus had not sharp edges, not even a definitely round form, but was like a light shining through a fog. Its diameter was about 112 miles, or, if we take only the central light, 70 miles; speaking roughly, as large as the State of Connecticut. The whole cloud, as seen in the telescope, was some 6,000 miles in diameter; to the naked eye perhaps 30,000 miles. How much smaller than 70 miles was the hard part of the nucleus, we cannot say.

Position in 1826.—In 1826 it was first seen from A in the line A*a* (Fig. 3). Astronomers followed it with care, as they had come to know that it was a comet of short period, and not many such were then known. Its path then crossed just inside the earth's orbit at the node, but only $\frac{1}{100}$ of an inch in the diagram, or 20,000 miles, in fact, from it.

Position in 1832.—Six and two-thirds years bring us to 1832, and you can readily imagine with what interest this first predicted return was watched for. Some of you also remember the widespread, though groundless, fears at that time of a collision of the earth and the comet. The comet was first seen by Sir John Herschel, in September. In his 20 foot reflecting telescope he saw it pass centrally over a group of small stars of the 16th or 17th magnitude. The slightest bit of fog would have at once blotted out the stars. Through the comet, however, they looked like a nebula, resolvable, or partly resolvable, into stars. How thick the cometic matter was we do not know. Its extent, laterally, was not less than 50,000 miles. Again, M. Struve saw it pass centrally over a star of the ninth magnitude. A like star was seen in the telescope at the same time, so that he was able to say that the comet did not dim in the least the one which it covered. The comet, as the figure (Fig. 4) shows, was in 1832 always at a great distance from the earth.

Another six and two-thirds years brings us to 1839. The comet came to perihelion, at P, in July. The earth and comet were on opposite sides of the sun both before and after July, and of course the comet was not seen.

Position in 1845.—Another circuit was finished in 1845–46. The comet was visible then during five months, from *a* to *b* (Fig. 5), or as viewed from the sun through nearly half its circuit. At this time it was that the comet became all at once famous.

On the 29th of December Mr. Herrick (then Librarian of Yale College) and Mr. Francis Bradley (then in the City Bank) were watching the comet through the Clark telescope in the Atheneum tower yonder. They saw a small companion comet beside the larger one! What did it mean? Had the comet a satellite like the earth's moon? Or had the comet been split by some convulsion? Two weeks later the companion comet was seen by Lieut. Maury and Professor Hubbard at Washington, and two days after that, it was seen by two or three European astronomers.

Changes were seen in the larger telescopes that increased the mystery. The faint companion grew in size and brilliancy. Each comet threw out a tail. Then the smaller one had two tails. Then the larger one had a pointed, or diamond-shaped, rather than a round head. Two nuclei were seen in the larger one, and it also had two tails. An arch of light was thrown over from one to the other. For some days in February the companion was the brighter of the two. Presently three tails were seen running from the primary, and three cometary fragments (one observer says five) around its nucleus. What could it all mean? Do you wonder that astronomers were excited by these wizard changes?

The companion comet was seen in Washington by Maury and Hubbard two weeks after it was seen here by Herrick and Bradley. Professor Joseph Hubbard was the son of a resident of New Haven, well known to many of you from his connection with the New Haven Bank. Professor Hubbard was graduated two years before (in 1843) at this college, and was now professor in the Naval Observatory at Washington. He took up the study of the motions of the two Biela comets as special work, outside of his hours on duty. How faithfully he worked, four thick manuscript volumes of figures might tell. I cannot show you those books. They form, since Professor Hubbard's death, a cherished memento in the possession of a friend. But I have brought another of Hubbard's volumes from the College Library, one of three upon the comet of 1843, in order to show you by what patient labor some of the results of astronomy must be wrought out. In your school days you called it a wondrously long sum that covered both sides of the slate. On the leaves of this book there are as you see one, two, three, and in some cases, I think, even four thousand figures upon the page. You will, I am sure, excuse me from telling in detail to-night how we learn about the sizes, distances, and motions of the comets. Eight or ten such volumes of figures, to be increased in time, we hope, by the four Biela volumes, form a monument to a true, devoted, gentle scholar of science. You will not wonder when I tell you that he hated shams.

Positions in 1852.—In 1852 the comet was always at a great distance from the earth (Fig. 6), and only to be seen through the largest telescopes. The changes of size and brightness of the two comets were remarkable, and as they could but just be seen, sometimes one and sometimes the other alone was visible; which one it was that a person saw at any time was only told by computation afterward.

The two comets were now eight or ten times as far apart as they had been seven years before. They were at the point P, 1,250,000 miles apart. Professor

* The renewed interest in Biela's comet created by the great shower of meteors on the 27th of November last, justifies giving space for this lecture.—[Eds. Jour. Science.]

Hubbard found that he could not tell which comet of 1852 was preceding and which following, in 1845. One supposition agreed as well with the observations as the other.

Perhaps the knowing ones among you have noticed that the arc from the node to the point marked Jan. 10, in the first diagram, is too large for one month, for in 1772 the earth passed the node Dec. 9. But you will notice that when the comet is at D, and the large planet Jupiter is near by, he draws the comet toward the plane of the figure. The result is to bring the comet down to meet the earth's orbit farther from P. The node thus went back from Dec. 9 to Nov. 27, a distance of 12 days, or 12 degrees in the circle. The figure represents this last orbit. By the same cause the inclination was reduced one-fourth, or from 17° to 12°.

Since September, 1852 (with one doubted exception to be spoken of), neither of the two Biela comets has been seen. In 1859 their path was to us behind the sun. In 1866 they should have been at the point P on the 26th of January. A better chance of seeing them could hardly be. They were at all times to be away from the sun's light, and when nearest to the earth not more than one-fifth the sun's distance. The paths were carefully computed, and the action of all the planets, notably that of Jupiter, allowed for. A dozen observers for months swept the heavens with their telescopes, but not the slightest trace of the comets was seen.

Again, they should have come to perihelion a year ago last autumn (Oct. 6, 1872), but, as I suppose, neither of them was seen. With the loss of its hero, our story would seem to come to an end. I must ask your indulgence, however, for another chapter.

I suppose that each one of you has often seen a shooting star. On a clear night you have seen a bright point of light travel quickly across the sky, as though a star had been shot from its place in the firmament. It may, if it was a large one, have broken into sparks as it disappeared, or have left a cloudy train along part of its path for an instant; or perhaps it was so faint even that you could not be quite sure that you saw anything. Some of you have seen those shooting stars by hundreds in star showers.

Until near the close of the last century, poets dreamed, and other men guessed, about these objects, but knew nothing. Two German students, Brandes and Benzenberg, found out, and told us, that these bright flights were in the upper parts of the atmosphere. From the two ends of the city a track always appeared to be in the same part of the heavens. But when one went to a village many miles away, a track was seen by the two persons (at A and B, Fig. 8), in different parts of the sky. Hence they were able to measure the height of the shooting stars from the ground.

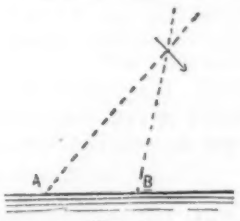


FIG. 8.

We now know that these luminous paths are rarely less than 40 miles or more than 90 miles from the earth. We also know that any shooting star was a small body of unknown size, perhaps not larger than a pebble or a grain of coarse sand even, undoubtedly solid, which has been traveling around the sun in its own independent orbit, like any planet or comet. Its path came within 4,000 miles of the earth's center, and so the small body struck into the earth's atmosphere. Its velocity was so great—fifty or a hundred times that of a cannon ball—that even in our rare upper atmosphere an intense light and heat were developed by the resistance, and the body was scattered in powder or smoke. These bodies, before they come into the air, I call meteoroids. It is only when they have reached our atmosphere and begin to burn that we ever see them. They are then within 90 miles of the ground.

Brandes, one of the two German students spoken of, was riding in an open post-wagon on the night of Dec. 6, 1798, and saw and counted hundreds of these shooting stars or meteors. At times they came as fast as six or seven a minute. These meteors which Brandes saw that night we know now were bits from Biela's comet. In November, 1833, occurred the famous star shower, which some of you saw. The facts of that shower gave to two New Haven men, Professor Twining and Professor Olmsted, the clew to the true theory of the shooting stars. From that date shooting stars have belonged to astronomy. The November meteors were admitted a new constituent of the solar system. Three years later, M. Quetelet, of Brussels, found that shooting stars are to be seen in unusual numbers about the 10th of August of each year. A few months afterward Mr. Herrick made independently the same discovery; but he also told us of star showers in April and January. What Brandes had seen in December, 1798, led Mr. Herrick, moreover, to expect a like shower in other Decembers, and he asked that shooting stars be looked for on the 6th and 7th of December, 1838. This shrewd guess was justified, for on the evenings of those days hundreds of these meteors were seen in America, in Europe, and in Asia by persons thus induced to look for them. These shooting stars also had once been parts of Biela's comet, though this fact was not dreamed of at that time.

In the course of time we came to know more about the meteoroids: that in general they moved in long orbits like comets, rather than round ones like planets; that some of them were grouped in long, thin streams, many hundreds of millions of miles long, and that it was by the earth's plunging through these that we have star showers; that the space traveled over by the earth has in it everywhere some of these small bodies, probably the outlying members of hundreds of meteoroid streams.

Also the periodic time and the path of the stream of November meteoroids were found out. Then came the interesting discovery that in this stream, and in that of the August meteoroids, lay the paths of two comets. Then Dr. Weiss, of Vienna, showed that the meteors seen by Brandes in 1798, and by Herrick in 1838, as well as many meteors seen near December 1 of other years, and the Biela comets, all belonged to each other.

It is then properly a part of my story to show you the behavior of one of the streams of meteoroids. Standing several hundreds of miles away, see them enter the upper atmosphere. They are entirely unseen until they strike the air. They then come down like drops of fiery rain a few miles in parallel lines, burning up long before they reach the ground (see Fig. 9). The air is in fact a shield, protecting the men below from a furious bombardment. The region of the luminous tracks is many miles above that of the highest mountains.

FIG. 9.

Go farther away. Parallel lines may show the paths of the meteoroids, though the bodies themselves are too small to be seen. They strike a little way into the air, to some persons coming from the zenith, to some coming obliquely, to some skimming through the upper air, and unseen by all upon one whole hemisphere.

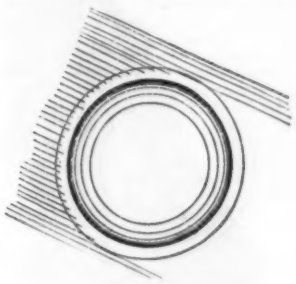


FIG. 10.

I need hardly remind you that sunlight, and twilight, and clouds often come in to prevent the seeing of the star-flights by persons below.

Go still farther away. From outside look in toward the sun upon the earth and meteoroid stream. The meteoroids in fact are not to be seen. The stream is of unknown depth, perhaps millions of miles deep. Its density increases in general toward the center. We cross the densest part of the November stream in two or three hours, and the whole of it in ten or fifteen hours, while the passage of the August stream requires three or four days. The Biela stream is crossed obliquely, the meteoroids overtaking the earth. The August stream is nearly perpendicular, and the November stream meets the earth.

Again go still farther away, out to the point from which we first looked down upon the earth and comet. We then see (by the mind's eye) the meteoroids strewn along the elliptic orbit of the comet for hundreds of millions of miles, forming a stream of unknown breadth, but in the scale of the first figure shown you, about one-fiftieth of an inch in thickness.

Come back now and stand inside the stream, at its densest part. You in fact see nothing; but the meteoroids are all about you scattered quite evenly, and distant each from its nearest neighbors 20 or 30 miles. They all travel the same way and with a common motion.

Once more change your place and look up from the earth's surface. The meteoroids can now be seen, for when they strike the air they burn with intense light, becoming shooting stars. As it is from this position only that we ever see them, note their behavior with more care. A shooting star coming toward you appears only as a bright stationary point in the sky. That point is a marked one in every star shower, and is called the radiant. The meteors to the right and left of the stationary one are, in fact, moving in the common direction, but they seem to move in the sky away from the radiant (Fig. 11). In other words, the tracks produced backward will all meet in one point in the sky (Fig. 12). This radiant point may be in the horizon, or in the zenith, or at any place between. It will in general rise in the east and set in the west, like the sun or a star, keeping always its fixed place among the stars.

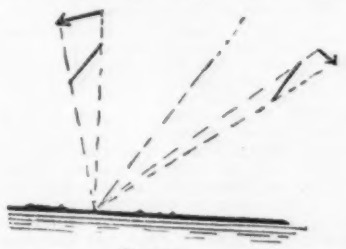


FIG. 11.

FIG. 12.

Need I tell you how much we would like to have some of these bits from the meteoroid streams to handle, to try with the blowpipe and under the microscope, perhaps thus to learn something of their history? We do have something like this. At times large meteor masses come crashing into the air. They burn with a light bright enough to be seen over several States. Coming down usually a little lower than the shooting stars, most frequently to a height of twenty-five or thirty miles, they break up with a noise like the firing of heavy artillery, to be heard over several counties. Fragments scattered in every direction fall to the ground over a region ten or twenty miles in extent. I can show you several such fragments. There are over a hundred of them in our college cabinet, one of which weighs nearly a ton.

Between these stone producing meteors and the faintest shooting star I cannot find any clear line of division. We have meteors that break with a loud detonation, but no fragments are seen to fall. One such was seen in 1860 from Pittsburg to New Orleans, and from Charleston to St. Louis. It exploded over the boundary line of Tennessee and Kentucky. We have others which are only seen to break into pieces, no noise being heard. Then we have those which quietly burn out. Like the larger ones, these may have smoky trains that last for minutes. One such I have seen for 45 minutes as it slowly floated away in the currents of the upper air.

Thus through the whole range, from the meteors that give us these stones and irons for our museums down to the faintest shooting star hardly seen by a person watching for it, we pass by the smallest differences. They differ in size, in color of flame, in direction, in train, in velocity. But in astronomical character all seem to be alike. They move in long orbits like comets, and, like comets, at all angles to the earth's orbit. In fact, a meteoroid is a small comet, not having, however, the comet's tail.

Let us turn from this long digression again to the story of Biela, and tell you what we saw of it in November, 1872. We of course looked for a few fragments from the comet the last week in November, but not quite as early as the 24th. But on that evening they came, in small numbers it is true. Before midnight we saw in New Haven about 250 shooting stars, three-fourths of them from Biela. Very few of them were to be seen the next morning and evening. Then for a day or two it was cloudy. But in the early part of the evening of the 27th they came upon us in crowds. Over 1,000 were counted in an hour. By 9 o'clock the display was over. But we saw only the last few drops of a heavy shower. Before the sun had set with us the shooting stars were seen throughout all Europe, coming too fast to be counted. At least 50,000, perhaps 100,000, could have been seen then by a single party of observers.

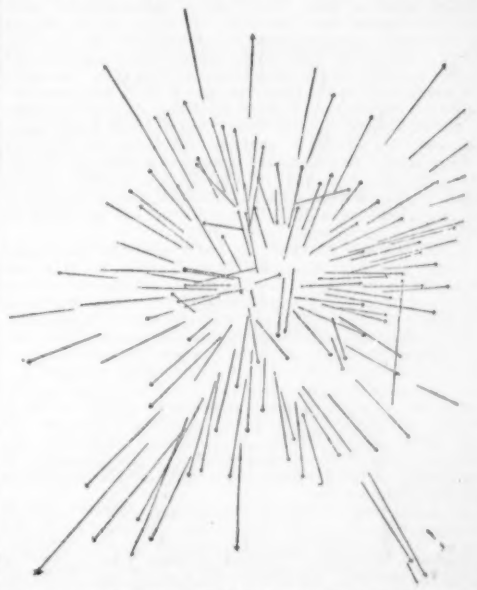


FIG. 13.—METEORS SEEN IN ITALY, NOV. 27, 1872.

Notice what was really seen. Here is a chart of the paths of the shooting stars as actually seen on that evening, and drawn with care at the time upon maps of the stars. You see a few stray flights cutting wildly across the others. These are strangers to the system.

You see also that the paths do not, as we had reason to expect, all meet in one point. This is not due to errors of observing, for we see it in every star-shower. It is probably because the small bodies glance as they strike the air, just as a stone skips on the water. In fact, we often see the meteors glance in the air—the paths being crooked.

The meteors came from the northern sky. A German astronomer, Professor Klinkerfues, at once thought that if this was the main body of the comet it ought to be visible as it went off from us. For this, however, we must see the southern sky. He telegraphed to Mr. Pogson, at Madras, in India: "Biela touched earth Nov. 27. Search near Theta Centauri." Mr. Pogson looked for the comet, and found it. On two mornings he saw a round comet with decided nucleus, and having on the second morning a tail eight minutes long. But clouds and rain returned the next day. This is the last that has been seen of Biela's comet.

Was this Pogson comet one of the two parts of Biela seen in 1845 and 1852? This is yet an open question among astronomers. It may have been, but I think it was not. The Biela comets should have been nearly 200,000,000 miles away. Their orbits had been computed with care. The comets, as single or double, had

been observed for 80 years, that is 12 revolutions, and we knew well their orbits. All known disturbing forces had been allowed for. It could hardly be that they should have gone so large a distance out of the way. It is much more probable that this was a third large fragment, thrown off centuries ago. The two observations made by Mr. Pogson were not enough to compute an orbit from, but they do show that his comet was very near us, and were such as one traveling in the Biela stream might give. But they also show that the earth did not pass through the Pogson comet centrally.

Orbit of the Biela Meteors.—In 1798, when the earth was at N, and Brandes saw the fragments from Biela, the comet was at C (Fig. 7). In 1838 Mr. Herrick and others saw such fragments of the comet at N, 300,000,000 miles ahead of the main body at A, and in 1872 we met like fragments at N, 200,000,000 miles behind the main body, which should have been at B. Thus the fragments are strewn along the comet's orbit, probably in clusters, for at least 500,000,000 miles.

My story of Biela's comet and of its fragments has covered 100 years. Do we get any glimpses of its earlier life, and can we guess how it grew into its present shape? Yes; we may make our hypothesis. But we must not forget that to tell others how God must have made the world is bewitching to many minds, and that of the thousands of trials at world building almost all have been grievous failures. With this caution let me give you a plausible form of this early story of Biela.

Once upon a time, hundreds of thousands of years ago, this comet was traveling in outer space, among the fixed stars, too far away to be attracted by the sun. What I mean by this outer starry space may be told by the help of the pictures I have shown you. In them the earth's distance from the sun is 10 inches, and the comet's longest range about five feet. Upon the scale of these figures only a few of the nearest fixed stars, perhaps two or three only, would be in the State of Connecticut. In this starry space the comet was traveling. What had happened before I do not try to guess. How, when, by what changes, its matter came together, and had become solid, I do not know, nor whether, in fact, it had not always been solid.

In the course of time its path and the sun's path through space lay alongside of each other, and the sun drew the comet down toward itself. If the comet had met no resistance as it ran around the sun, whether from the ether that fills space or from the sun's atmosphere, and if it had not come near any of the planets, it would have gone off again into outer space whence it came. Some such cause robbed it of a little of its momentum, and it could not quite rise out of the sun's controlling force, but it came around again in an elliptic orbit to remain thenceforth a member of the solar system. It may or it may not then have been a great comet, like Donati's (in 1858). It was probably a small one. It may have made its circuit of the sun in tens of years or in tens of thousands.

At some time, probably in the early historic ages, it came near the large planet Jupiter. When it had gone out of his reach, it had just momentum enough left to go around the sun in its present orbit of 6¾ years. It went away from Jupiter an entire and single comet. As it came near the sun, his burning heat acting upon the cold rocky body of the comet cracked off and scattered in every direction small angular bits. At the same time a very thin vapor, shining by its own light, was set free. To this vapor both comet and sun had an unaccountable repulsion. It was driven off first by the comet every way. But soon that which was sent toward the sun was driven back again, and it went streaming off into space to form the comet's tail, a process ably set forth by Professor Norton.

This matter which made the tail of the comet never got back. It had, moreover, nothing whatever to do with the meteoroid stream. The meteoroids are solid fragments. To them the sun, at least, had little repulsion. The comet was so small that perhaps the force with which a boy can throw a stone would have sent the bits of stone entirely off the comet, never to come back. Those which were shot forward from the comet near P (first figure) went up along the orbit with greater velocity and rose higher from the sun than the comet did near D. Having a longer road to travel, they took a longer time to come round to P in each circuit. On the other hand, those bits which were shot backward followed the comet with less velocity and could not quite rise to D, and so having a shorter road to go over came sooner back to P, gaining on the comet at each circuit. Thus the stream grew longer slowly, and new fragments being thrown off at each circuit, the meteoroid stream grew in length to its hundreds of millions of miles. At times, the main comet has broken into two or more parts, giving us the double comets of 1845 and 1852, the Pogson comet of 1872, and the double meteor stream of November, 1872.

UNEDUCATED REASON IN THE CICADA.

By J. S. NEWBERRY.

IN 1877, a colony of the seventeen-year locusts (*Cicada septen. decim.*) appeared at Rahway, N. J. During the interval between the appearance of that and the preceding generation, the town had been extended, and some houses had been erected where forests or fields existed before.

One of these houses—that belonging to Mr. Alonzo Jaques—was constructed on the site of an old orchard, and had a shallow cellar. This cellar was kept closed till about the time of the advent of the cicadas; the door was then opened, and the bottom of the cellar was found to be thickly set with mud-cones or tubes, from six to eight inches high, an inch to an inch and a half in diameter, each of which had been formed by the pupa of a cicada, that had emerged from the earth beneath the cellar. Finding a dark chamber, and apparently desiring to work up to daylight, the cicadas had taken the moist clay, and of this formed pellets, with which the tubes were built up, apparently with the purpose of bridging over the vacancy and thus reaching the surface.

These facts appeared to me so interesting that I procured a large number of the tubes, one of which is here figured, and I had the first report verified by the written testimony of the owner of the house and several other well-known citizens of Rahway.

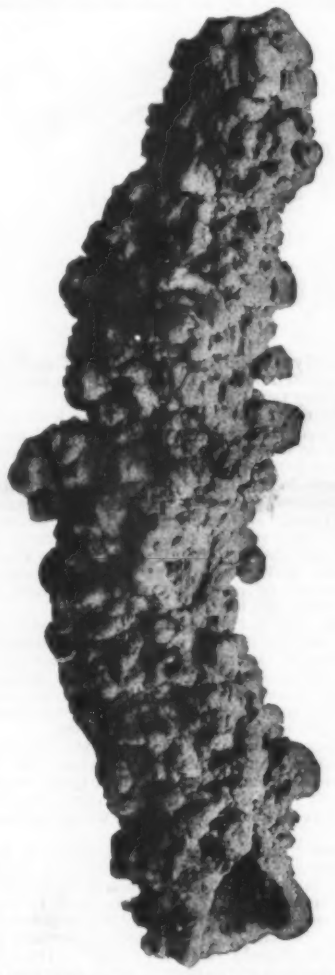
The document sent me with the tubes has remained in my possession to the present time. It is dated June, 1877, and reads as follows:

"These cones were erected by the pupas of the cicada in the cellar of a house belonging to Alonzo Jaques, Rahway, during parts of May and June, 1877. They were built in an unfloored cellar of a house constructed about eight years ago, in an old orchard. The cellar was dug to about the depth of a foot in red clay and the bottom covered by a slight layer of debris, sand, sticks, etc. The cellar was perfectly dark during the construction of the cones, the only opening being shut. The locality is a dry one, the house being situated on a rise of ground, and about a quarter of a mile from the nearest water—a ditch dry in summer. These cones were not seen in the course of erection, but when the cellar was opened, about the time the locusts made their first appearance, the whole cellar bottom was covered by them. The tops of all were closed, but on breaking some of them the pupas were seen both in the hole in the ground and in the cone.

"After the cellar had been opened and left so, they appear to have stopped building, and to have made holes in the tops of the cones for their exit. These cones were a great curiosity to the people of Rahway, and many came to see them, declaring them something entirely new in their experience.

(Signed) A. E. CROW,
ALONZO JAQUES,
W. B. DEVRIE,
M. L. CROW."

In the facts cited above we have evidence of the exercise of intelligence in the cicada, and a judicious adaptation of means to an end in circumstances that it would seem must have been without precedent in the



TUBE FORMED BY PUPA OF CICADA.

experience of that or any preceding generation; and, therefore, for which no education of ancestors could have given a preparation. It is possible that the pupa of the cicada is sometimes embarrassed in its ascent to the surface, by water, by too wet or too dry sand or mud, but it is hardly possible to imagine circumstances where the construction of a tunnel would be necessary.

In the earth, caves of any considerable size rarely or never occur, since surface water is constantly flowing through all superficial materials, and filling cavities with transported matter. Caves often occur in rocks, but the cicada has no power to penetrate rock, and lives in earth near the surface.

Perhaps some of those who have made the habits of the cicada a study can suggest a school in which they could have received the training that fitted them for the engineering work they have attempted in the case under consideration; yet, though I have studied the habits of various colonies of the cicada with some attention, I am quite at a loss for any explanation of the phenomena that will bring them within the scope of the theory according to which all our organs and faculties are the result of formative influences progressively developed through a long line of ancestry.

In whatever way the problem shall be solved, it has seemed to me of sufficient interest to warrant placing the facts on record.—*S. M. Quarterly.*

COMBES' APERIENT.—Sulphate of magnesia, 35 parts; roasted coffee, 40 parts; boiling water, 500 parts. Boil for two minutes, filter, and sweeten to taste with white sugar. One wineglassful in the morning fasting.—*Health.*

HEAT VALUE OF COAL GAS.

THE average heat value of well purified coal gas at constant volume has been recently determined by M. Witz—*Ann. de Chim. et de Phys.*—as about 5,200 calories per cubic meter at 0 deg., and 760 mm. when the water formed is fully condensed. This value, got from a great variety of experiments with gas from different works, appears to make the generally accepted figure of 6,000 calories about 15 per cent too high, and the calculation of gas motors is here concerned. The heat value of the gas from one and the same works varied in the course of a year from 4,719 to 5,425 calories, which was more than the variation between different works. The influence of temperature and external pressure was not perceptible. The operations for purifying gas diminish the heat effect sometimes as much as 5 per cent. The gas of the last hour of distillation is—contrary to the usual view—less, *Nature* says, rich than that of the first hour. Dilution with oxygen lessens the heat value; but in dilution with air, curiously, no such effect was observed; the heat of combustion was the same with six or with ten volumes of air.

A CATALOGUE containing brief notices of many important scientific papers heretofore published in the SUPPLEMENT, may be had gratis at this office.

THE

Scientific American Supplement.

PUBLISHED WEEKLY.

Terms of Subscription, $5 a year.

Sent by mail, postage prepaid, to subscribers in any part of the United States or Canada. Six dollars a year, sent, prepaid, to any foreign country.

All the back numbers of THE SUPPLEMENT, from the commencement, January 1, 1876, can be had. Price, 10 cents each.

All the back volumes of THE SUPPLEMENT can likewise be supplied. Two volumes are issued yearly. Price of each volume, $2.50 stitched in paper, or $3.50 bound in stiff covers.

COMBINED RATES.—One copy of SCIENTIFIC AMERICAN and one copy of SCIENTIFIC AMERICAN SUPPLEMENT, one year, postpaid, $7.00.

A liberal discount to booksellers, news agents, and canvassers.

MUNN & CO., Publishers,
361 Broadway, New York, N. Y.

TABLE OF CONTENTS.

PAGE

I. CHEMISTRY, ETC.—Detection of Adulteration of Olive Oil.—By A. AUDOYNAUD..... 8511
A Theory of the Connection between the Crystal Form and the Atom Composition of the Chemical Compounds.—A paper read before the British Association by WM. BARLOW.—16 figures..... 8512

II. ENGINEERING AND MECHANICS.—Amount of Horse Power used in propelling Street Cars.—A paper read by A. W. WRIGHT before the Western Society of Engineers..... 8509
Sibley College Lectures.—On Steam Boilers.—By J. M. ALLEN.—Steam the great motive power.—The horizontal tubular boiler.—Boiler making.—Fractures.—Bracing of boiler heads.—Staggering of tubes.—Sediment and scale.—Explosion..... 8510
The Permissible Strain upon Brickwork.—By Dr. BOHME..... 8511

III. TECHNOLOGY.—Roman Carpentry.—By Prof. HOSKING..... 8506
Manufacture of Artificial Gems.—By HERMAN REINBOLD..... 8507
The Pandiscope or Lantern Sketcher and the "Presto" Photographic Slide Carrier.—3 figures..... 8508
Tin.—Physical properties.—Permanence of polish.—Tin foil.—Tinning copper.—Disintegration of tin..... 8511

IV. ART AND ARCHITECTURE.—Design for a Monument.—By KLOTZ.—With engraving..... 8503
Artistic Bronze Casting.—A lecture by GEO. SIMONDS.—Sculptor's first sketch.—Full-sized study.—Moulds.—Process of piece moulding.—Waste wax process.—Pouring the bronze.—The furnace..... 8503
Harlow Vicarage, Essex.—An engraving..... 8507
Design for a Village Church Organ, by CHIPPENDALE..... 8507

V. ASTRONOMY, ETC.—The Micrometer Threads and Wires of Astronomical Telescopes.—5 figures..... 8508
The Story of Biela's Comet.—By H. A. NEWTON.—A lecture delivered at the Sheffield Scientific School of Yale College.—13 figures 8516

VI. NATURAL HISTORY.—Uneducated Reason in the Cicada.—By J. S. NEWBERRY.—With engraving of a tube formed by pupa of cicada..... 8513

VII. PHYSIOLOGY, ETC.—Sight for the Blind.—Application of an artificial cornea.—4 figures..... 8514
Stunning and Burn by an Electric Lamp.—By GEO. BUCHANAN.. 8514
Fireproof Individuals.—Fire eaters.—Volatile liquids.—Fireproof clothing..... 8515

VIII. MISCELLANEOUS.—Progress of the Telegraph in China..... 8512

IX. BIOGRAPHY.—Sir ROBERT S. BALL, F.R.S., Astronomer Royal of Ireland.—With portrait..... 8506

PATENTS.

In connection with the **Scientific American**, Messrs. MUNN & Co. are solicitors of American and Foreign Patents, have had 42 years' experience, and now have the largest establishment in the world. Patents are obtained on the best terms.

A special notice is made in the **Scientific American** of all inventions patented through this Agency, with the name and residence of the Patentee. By the immense circulation thus given, public attention is directed to the merits of the new patent, and sales or introduction often easily effected.

Any person who has made a new discovery or invention can ascertain, free of charge, whether a patent can probably be obtained, by writing to MUNN & Co.

We also send free our Hand Book about the Patent Laws, Patents, Caveats, Trade Marks, their costs, and how procured. Address

Munn & Co., 361 Broadway, New York.
Branch Office, 622 and 624 F St., Washington, D. C.